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LIMNOLOGICAL STUDIES OF WESTERN LAKE ERIE

I. PLANKTON AND CERTAIN PHYSICAL-CHEMICAL DATA OF THE BASS ISLANDS REGION, FROM SEPTEMBER, 1938, TO NOVEMBER, 1939

DAVID C. CHANDLER

Franz Theodore Stone Laboratory

The Ohio State University

Put-in-Bay, Ohio

INTRODUCTION

One phase of the fisheries research program now in effect at the Stone Laboratory is the year-round quantitative study of the basic fish foods in the region of the Bass Islands of Lake Erie, and of the ecological factors affecting the various components of this food. The present paper is the first of a series dealing with this subject and it is concerned primarily with year-round data derived from weekly plankton collections and certain physical and chemical determinations in this vicinity. The region of the Bass Islands, like the rest of the shallow western end of Lake Erie, serves as the spawning and feeding grounds for many fish of commercial value. The specific area selected for study was chosen because of its accessibility from the Stone Laboratory and its suitability for winter work due to the fact that from late December to late March it possesses an ice-cover through which investigations can be conducted safely.

Often the bulk of a given species of fish caught during so-called good years belongs to a single year group, the members of which were hatched several years previously. Annual fluctuations in abundance of a species and the dominance of this species by a single year group, as revealed by analyses of commercial catches in this region, immediately suggest that environmental conditions antecedent to time of maturity of a fish may be of considerable significance. It is conceivable that an abundance of fertilized eggs may be produced during the spawning period of a species but due to unfavorable physical and chemical conditions of the water, or to the lack of proper planktonic food for the newly hatched young, few mature fish will be produced. Since utilization of plankton by adult or immature fish depends upon its abundance and its availability, a plankton investigation becomes an essential part of this program. Data in this paper are general in nature but nevertheless they furnish a basis for future work.

The writer is indebted to Leonard J. Bodenlos, of this laboratory, for valuable assistance with all phases of this investigation; to Kenneth H. Doan, also of this laboratory, for statistical treatment of certain data; to Professor K. Y. Tang, Department of Electrical Engineering, The Ohio State University, for help with the calibration of the photometer; and to other associates who assisted from time to time.

REGION STUDIED

Three natural divisions exist in Lake Erie: the deep eastern portion (that east of a line connecting the city of Erie and the tip of Long Point) with a maximum depth of 64 meters, the central area (that portion west of Long Point and the city of Erie to a line connecting Point Pelee and the city of Sandusky) with a maximum depth of 24.5 meters, and the shallow western end (the remaining portion of the lake) with a maximum depth of 16 meters (Fig. 1). General limnological surveys of these three divisions have been made; the report dealing with the eastern end has been published by Fish (1929), and a summary report of the investigations of the western end has been published by Wright and Tidd (1933). A report pertaining to the studies of the central area has not been published as yet. The present paper is concerned with only a portion of the western end of Lake Erie, that part in the immediate vicinity of the following islands: South Bass, Middle Bass, North Bass, Rattlesnake, and Green (Fig. 2). This region is referred to in this paper as the Bass Islands Region. Wright and Tidd (1933) studied the entire western end of the lake and divided it into several sections, one being designated as the "Island Section" which included approximately the eastern two thirds of the western end of the lake. The Bass Islands Region should not be confused with the much larger "Island Section"; however, except for size these two divisions are quite similar as will be shown later.

The present investigation was confined to an area, consisting of approximately 1000 acres and uniformly 9 to 10 meters deep, lying between the following islands: South Bass, Middle Bass, Rattlesnake, and Green (Fig. 2). Due to currents and wind action this shallow water is kept in continuous circulation throughout most of the year. During winter an ice-cover is formed in this region and extends various distances depending upon the severeness of the winter. Some winters result in an ice-cover forming over the entire western end of the lake, while others, like the winter of 1938–39, produce an ice-cover nearly limited to the Bass Islands Region. During this particular winter ice did not form until late December, 1938, and did not exceed two inches in thickness until late January, 1939. It later reached a maximum thickness of eight inches. The ice-cover remained until late March, but several times during this period it broke up and shifted away from the islands for a short time, later returning to produce a continuous ice-cover. Each time the ice broke up wind action produced violent churning of the water resulting in complete circulation and increased turbidity.

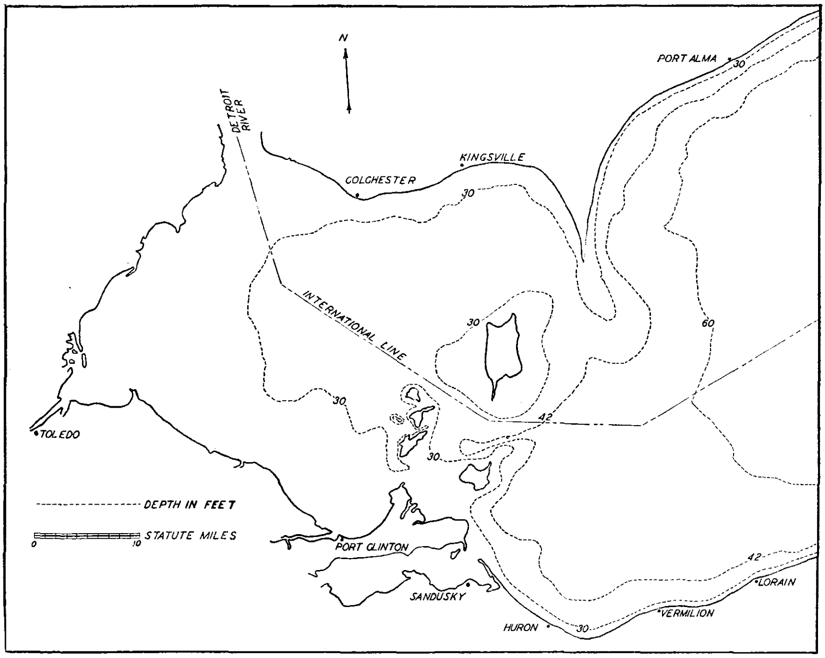


Fig. 1. Map showing the western part of Lake Erie. *Modified from the map of Lake Erie including the waterways between Lakes Ontario and Huron. Published by the U. S. Lake Survey Office June* 2, 1939.

Currents in this area, both surface and sub-surface, are known to exist, but no particular study was made of them. At times of high wind velocities large waves are formed which pound against the steep rocky shores, producing undertow currents of considerable magnitude. Also, these strong winds force the water between the islands setting up currents traveling in various directions. These and the undertow currents produce unpredictable disturbances which may be of considerable importance in respect to plankton distribution. During periods of ice-cover strong currents may be observed to flow in one direction for a few hours, then subside, and later a current will move in the opposite direction. Hook and line fishermen in this region claim that when the currents are strongest, fishing through the ice is best, irrespective of the direction of flow. This suggests that these currents may be an important factor in the movements of fish in this region.

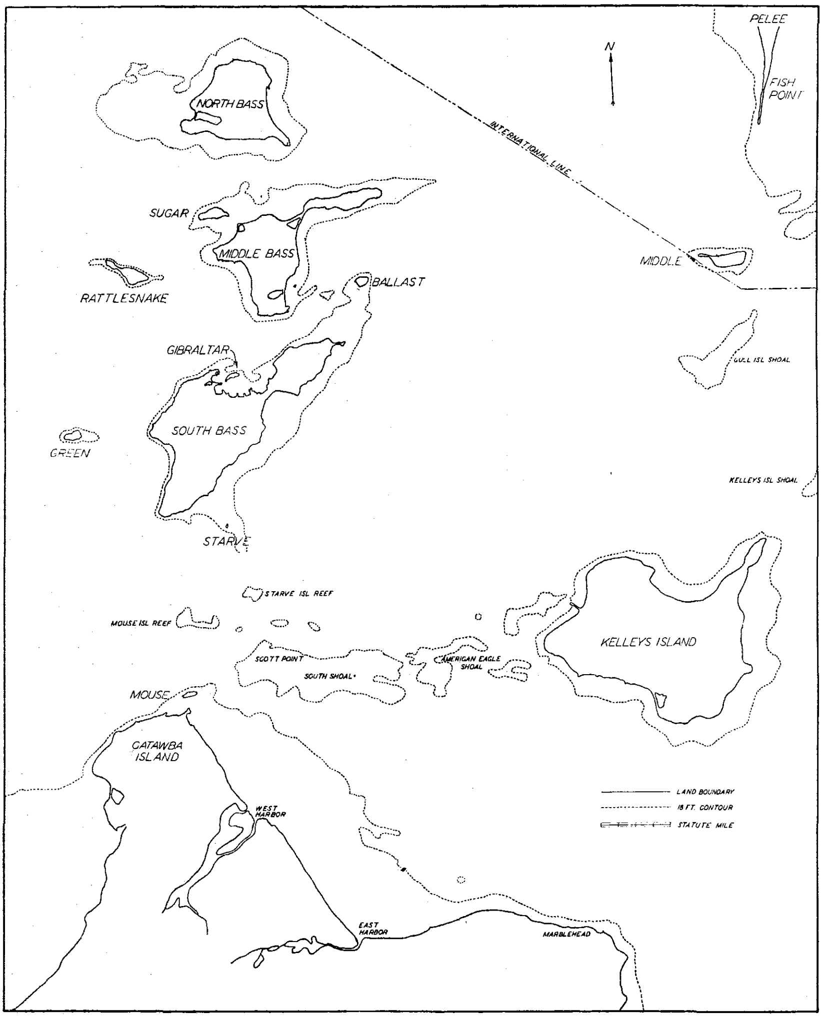


Fig. 2. Map showing the islands and shoals of Lake Erie in the vicinity of Gibraltar Island, on which the Stone Laboratory is located. *Modified from the map of the Islands in Lake Erie including Sandusky Bay, Ohio. Published by the U. S. Lake Survey Office July* 9, 1937.

Bottom sediments in the area studied consist of clay, sand, fine gravel, and organic detritus, appearing in various combinations. Some of these sediments are very compact indicating that they are constantly swept by currents, while others are soft and apparently free from the influence of currents. These sediments are being studied from the standpoint of organism content, and their mechanical and chemical nature, a report of which will appear at a later date.

METHODS AND EQUIPMENT

During periods of open water all collections were made from a scow (Fig. 5) which was towed to and from collecting stations by a motor boat. On the deck of this scow was mounted a davit equipped with a winch and meter-wheel. A 3-16 inch wire cable was threaded

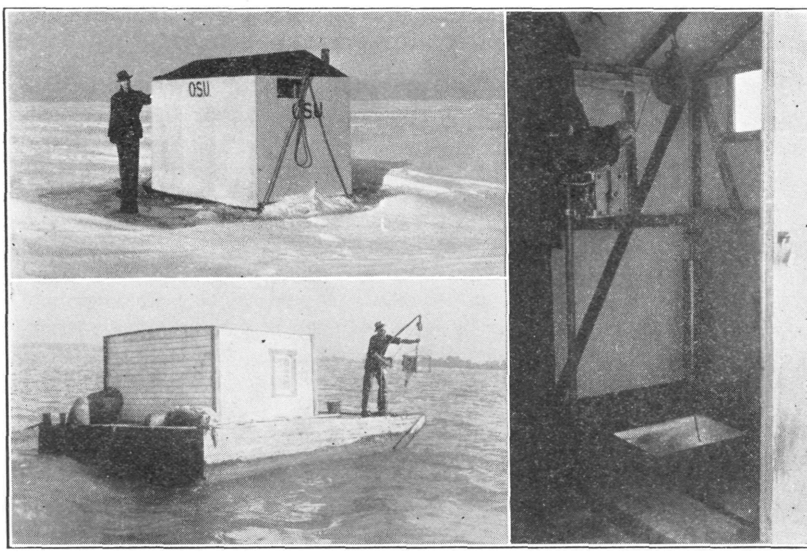


Fig. 3 (upper left). Shanty from which all collections through the ice were made.
Fig. 4 (right). Inside view of shanty showing arrangement of winch and meter-wheel.
Fig. 5 (lower left). Scow from which all open water collections were made.

from the winch through the meter-wheel and was used to raise and lower all equipment. When work was done through an ice-cover the same equipment was mounted in an ice-shanty (Figs. 3 and 4) 8 ft. long, 5 ft. wide, and 6 ft. high. In the floor of the shanty are two holes two feet square which make it possible for two persons to work simultaneously. A small stove installed in one corner keeps the shanty comfortably warm regardless of outside conditions. On two occasions collections were made from this shanty when the air temperature was —5° F. without experiencing any discomfort.

All temperature determinations were made with a Negretti and Zambra reversing thermometer. Temperatures were taken at intervals of 1 meter from the surface to bottom, when surface temperatures varied more than 2 degrees centigrade from those of the bottom; otherwise, determinations were made at the surface, 5 meters, 9 meters, and bottom. A continuous recording thermograph, recording air and surface water temperatures, was used to supplement field observations during the latter part of the investigation.

Turbidity was determined to the nearest 5 p.p.m. by means of the La Motte turbidity standards when turbidity did not exceed 100 p.p.m. When turbidity exceeded 100 p.p.m. a Jackson turbidimeter was employed.

Transparency was measured by means of a standard Secchi disc, suspended by a chain calibrated in centimeters. The disc was lowered until it disappeared, then raised until it appeared, and the average of the two readings was accepted as the transparency reading. All readings with this disc were made under shaded conditions. Readings through the ice were often made inside the shanty.

Light penetration was measured by means of a Weston photometer mounted in a water tight case, similar to the one described by Atkins, Clarke, etc. (1938). Readings were made of the intensity of total visible illumination in microamperes and milliamperes as recorded by a microammeter. The instrument was calibrated in foot candles and was found not to be sensitive to intensities less than 1.5 foot candles. Readings were made of direct sunlight in air and in water at the following depths: at intervals of 10 centimeters from surface to a depth of 1 meter, at intervals of 0.5 meter from 1 meter to 4 meters, and at intervals of 1 meter from 4 to 10 meters. Data were collected to show the intensity of total visible light at various depths as a percentage of surface light. When an ice-cover was present readings were made through a hole in the ice, either in the shanty or in the open.

Measurements of wind velocity at time of collections were made with a hand anemometer and stop watch. Velocity was expressed in miles per hour.

Water samples for all chemical analyses were collected with a modified Kemmerer water bottle. Hydrogen-ion concentration was determined by the La Motte colorimetric standards. Dissolved oxygen, free carbon dioxide, carbonates, and bicarbonates were determined by methods outlined in the Standard Methods of Water Analysis, 8th edition (1936).

Zooplankton was collected at intervals of 1 meter from surface to bottom by means of a 10 liter plankton trap, equipped with number 25 silk bolting cloth. Samples were preserved immediately with 4 per cent formalin and later were concentrated to 3 cubic centimeters with a pipette covered at the lower end with a double thickness of number 25 silk bolting cloth. The concentrate was placed in a 3 cubic centimeter counting chamber and all zooplankters were enumerated, and expressed in numbers per liter. At times of heavy pulses it was necessary to count only half of the sample and make the proper correction.

Phytoplankton collections were made at surface, at 5 meters, and at 9 meters, by collecting one liter of water with the water bottle. These samples were taken to the laboratory and centrifuged with a Foerst continuous flow centrifuge operating at 20,000 R. P. M. The concentrate was transferred from the centrifuge bowl to a vial and was preserved with 4 per cent formalin. Examination of these samples consisted of a qualitative and quantitive enumeration of phytoplankters with a Sedgewick-Rafter cell and a Whipple micrometer. In most cases the concentrate of each sample was diluted to 12.5 cubic centimeters; however, during periods of high turbidity it was necessary to dilute each sample to 25 cubic centimeters. The diluted sample was mixed thoroughly by shaking and then 1 cubic centimeter of it was transferred to the counting cell. All phytoplankters were counted in 10 cubic millimeters in each of two cubic centimeters of concentrate and this number was multiplied by the proper factor, usually 625, to convert to numbers per liter.

Unfortunately, many published phytoplankton data have lost their value through a failure of the investigator to state what units were used in counting various algae. In order that phytoplankton data of this investigation might be compared directly with that obtained by Wright and Tidd (1933) the same units have been adopted. The following have been considered as one unit: one cell of *Navicula*, *Stephanodiscus*, and *Synedra;* one colony of *Coelastrum*, *Coelosphaerium*, *Oöcystis*, and *Pediastrum;* 4 cells of *Scenedesmus;* 5 cells of *Dinobryon;* 8 cells of *Asterionella*, *Crucigenia*, *Diatoma*, and *Tabellaria;* 300 micra of *Melosira*, *Oscillatoria*, *Lyngbya*, *Anabaena*, and *Aphanizomenon;* and 100 micra of *Fragilaria.* Genera not mentioned above, when encountered, were assigned comparable units.

PHYSICAL DATA

TEMPERATURE

Temperature conditions of the water investigated are quite uniform from surface to bottom, due to shallowness and frequent agitation by wind action. Table I shows water temperatures at approximately weekly intervals from Sept. 2, 1938, to Oct. 26, 1939. It will be noted that on a given date temperature did not vary more than 2° C. from surface to bottom during this period, except on three occasions: May 9, May 23, and July 8, 1939. On these three dates thermal stratification was sufficient to form thermoclines. Temperature determinations at intervals of one meter, on May 9, showed that the top of the thermocline was at 5 meters with a temperature of 11.95° C. and the bottom at 8 meters with 9.91° C. No thermocline was detected during the following week, but on May 23 a thermocline reappeared. Temperatures on this date at intervals of one meter from 5 meters to bottom were as follows: 5 meters, 17.4° C.; 6 meters, 16.60° C.; 7 meters, 15.60° C.; 8 meters, 16.80° C.; 9 meters, 12.80° C.; and bottom, 12.60° C. This temperature series shows thermoclines between 6 and 7 meters, and 8 and 9 meters. At 8 meters the water temperature was 1.20° C. warmer than at 7 meters, which indicates that these conditions were temporary and probably due to currents. Again on July 8, a thermocline was found to exist between 5 and 7 meters. No doubt thermoclines existed on other dates than those mentioned, but it seems evident that thermocline formation is an irregular and temporary phenomenon, of little biological significance in this area.

Table I. Temperatures in Degrees Centigrade

Depth in Meters	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Nov. 29	Dec. 5	Dec. 15	Dec. 19
0	22.80	21.05	20.65	17.40	18.00	16.80	15.80	17.80	12.30	11.83	12.00	10.80	7.96	7.60	3.10	3.60	1.55	1.00
5	22.80	20.95	20.65	17.30	17.80	16.80	15.80	16.10	12.20	11.81	12.00	10.45	8.00	7.60	3.20	3.60	1.55	1.00
9	22.70	20.80	20.65	17.20	17.80	16.80	15.80	16.00	12.20	11.81	12.00	10.30	8.00	7.60	3.20	3.60	1.55	1.00

Depth in Meters	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	1.55	0.02	0.03	0.02	0.10	0.02	0.03	0.10	0.90	2.90	3.20	3.65	7.20	8.40	12.03	12.83	17.70	17.40
5		0.02	0.02	0.02	0.10	0.02	0.03	0.10	0.90	2.90	3.10	3.60	6.60	8.10	11.95	12.60	17.40	17.35
9		0.02	0.02	0.02	0.10	0.02	0.03	0.10	0.90	2.90	2.95	3.60	6.57	8.08	9.60	12.60	12.80	17.20

Depth in Meters	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
0	20.20	19.20	20.55	22.80	26.70	22.70	25.20	24.20	22.90	23.10	22.80	21.60	21.20	21.20	16.95	18.10	13.05	12.80
5	20.00	19.10	20.35	22.80	25.55	22.60	23.90	23.90	22.80	23.00	22.80	21.60	20.95	19.90	16.90	17.90	13.05	12.20
9	19.20	17.60	19.80	22.70	23.70	22.55	23.75	23.80	22.70	22.90	22.60	21.60	20.90	19.60	16.90	17.75	13.00	12.10

Surface temperature varied from a maximum of 26.7° C. on July 8, 1939, to a minimum of 0.2° C., under the ice-cover, during Jan. and Feb., 1939 (Fig. 8). It will be noted that water temperature for a given date did not vary more than 0.5° C. from top to bottom while the ice-cover existed (Table I). A definite ice-cover existed from Jan. 23 to April 1, 1939, at which time water temperature was less than 1.0° C., but as soon as the ice disappeared the temperature increased rapidly to approximately 3.0° C. and continued to increase until the summer maximum was reached.

TURBIDITY

Water in the Bass Islands Region is characterized by sudden changes in turbidity, ranging from 3 to 140 p.p.m. Turbidity is a factor which appears to have a marked influence upon the productivity of the water investigated. Attention is called to Figure 7, which shows graphically the variations in turbidity, based on weekly determinations from Sep-

TABLE II. Turbidity in p.p.m. For Twelve Consecutive Days During December, 1939

Date	Wind Velocity in m. p. h.	Turbidity in p. p. m.
December 12, 1939	10	45
" 13 "	18	70
" 14 "	6	55
" 15 "	6	30
" 16 "	10	20
" 17 "	10	20
" 18 "	3	10
" 19 "	4	10
" 20 "	15	25
" 21 "	20	60
" 22 "	20	70
" 23 "	5	40

tember, 1938, to November, 1939. Unfortunately, the importance of this factor was not realized at the beginning of the investigation; thus, turbidity was determined only once a week and usually on calm days since such days were chosen for general collections. It appears that these data are not truly representative of the average conditions of turbidity, but apparently represent the lower ranges, at least lower than an average based on daily determinations. Daily determinations of turbidity for 12 consecutive days during December, 1939, are recorded in Table 2. These data give a general idea of the degree of variation in turbidity and its relation to wind velocity. Strong winds from the west and northwest, after an extended calm period, may result in a rapid rise in turbidity of 35 p.p.m. or more within 24 hours. When the wind subsides turbidity decreases slowly during the first day due to continued waves and swells resulting from the storm. If several calm days follow in succession a large portion of the suspended material settles out and relatively clear conditions prevail. During the autumn of 1938 and spring of 1939, there were nearly as many windy days as calm; thus, water in this region was usually quite turbid.

Numerous observations from airplane and motor boat indicate that there is a marked irregularity in distribution of turbid waters in the immediate vicinity of the Bass Islands. Water between Catawba Point and South Bass Island (Fig. 2), known as the South Channel, is often more turbid than water in the area studied. A possible explanation for this fact is that during rainy periods the Portage River, and other rivers along the south shore, discharge highly turbid water into the lake. Some of this water may be carried to various parts of the lake but probably much of it follows along the shore. Often on crossing the South Channel by boat, clear and turbid areas with clearly defined boundaries are encountered, due probably to current action. Likewise, the North Passage, the water between the Canadian shore and the islands, is reported to contain less turbid water than either the South Channel or the Bass Islands Region. This difference is usually attributed to currents which bring in clearer water from the deep eastern end of the lake. It is apparent that the shallow western end of the lake does have highly turbid water most of the year, but it can not yet be stated that certain areas are consistently more turbid than others. It would appear that turbidity was rather uniformly distributed from top to bottom, since turbidity readings at surface, 5 meters, and 9 meters did not show much variation. The lower meter of water was sometimes more turbid than the water above it but usually the difference did not exceed 5 p.p.m.

Microscopic examination of suspended materials causing turbidity reveals fine sand, organic debris, particles of clay, and other sediments. Physical and chemical analyses of these materials are being made at this laboratory for the purpose of determining what role they may play in the cycle of dissolved elements in the water. Also, such a study will aid in tracing the source of sediments responsible for turbidity.

TRANSPARENCY

The maximum Secchi disc reading for the period of investigation was 2.1 meters, February 25, 1939, under the ice-cover; the minimum reading was 0.11 meter on April 5, 1939, shortly after the ice-cover disappeared. Seasonal variation in transparency is shown in Table III, while the averages for the seasons are as follows: September through December, 1938, 0.66 meter; January through March, 1939, 1.3 meters; April through May, 1939, 0.44 meter; June to September, 1939, 1.1 meters; and September to November, 1939, 0.8 meter. Greatest transparency occurred during winter when an ice-cover was present and also during summer months when calm weather prevailed. Lowest transparency existed in spring shortly after the ice disappeared while intermediate conditions prevailed during the autumn months.

Water in the Bass Islands Region is characterized by low transparency, a fact made evident by a comparison of the above data with data derived from investigations of the esatern end of Lake Erie and certain smaller inland lakes. Parameter (1929) reported a maximum Secchi disc reading of 10.5 meters, a minimum 2.0 meters, and an average of 5.0 to 6.0 meters for the eastern end of Lake Erie, from June 15, to September

15, 1928. Average reading for the Bass Island Region for a corresponding period was 1.2 meters. Raymond (1937) who made a year-round study of Bass Lake, Michigan, reported that the Secchi disc readings varied from 4.7 to 5.2 meters, the average being about 5 meters. Tressler (1940) who studied Chautauqua Lake, New York, obtained a maximum

TABLE III. Transparency As Determined By the Secchi Disc

Date	Trans-parency in Meters	Date	Trans-parency in Meters	Date	Trans-parency in Meters
Sept. 2, 1938	0.50	Jan. 10, 1939	1.01	June 5, 1939	1.00
" 7	0.66	" 23	0.84	" 14	0.51
" 16	0.68	Feb. 2	1.40	" 22	0.69
" 23	0.70	" 11	1.17	" 29	1.25
" 28	0.70	" 17	1.87	July 8	1.86
Oct. 5	1.13	" 25	2.15	" 22	1.69
" 12	1.04	Mar. 4	2.00	Aug. 1	1.50
" 17	1.24	" 10	1.92	" 11	0.78
" 26	0.60	" 20	0.92	" 26	1.45
Nov. 1	0.80	" 29	1.08	" 31	1.45
" 5	0.70	Apr. 5	0.11	Sept. 6	1.15
" 10	0.49	" 11	0.13	" 12	0.82
" 17	0.47	" 18	0.40	" 19	0.85
" 22	0.47	" 25	0.25	" 25	1.00
" 29	0.40	May 3	0.50	Oct. 3	0.61
Dec. 5	0.50	" 9	0.46	" 9	1.00
" 15	0.40	" 16	0.80	" 21	0.68
" 19	0.44	" 23	0.85	" 26	0.64
		" 30	1.25		

reading of 5 meters in December, and a minimum of 2.0 meters in August. Many Secchi disc readings higher and lower than those cited above have been reported but these furnish a basis for comparison.

It is realized that determining transparency by means of the Secchi disc is a rough method subject to many errors, but it does give a general idea of transparency and depth of light penetration. Many investigators have used this method alone for determining transparency, and in order to compare this lake with others the same method was used.

When work was begun it was planned to obtain quantitative data in respect to light penetration. The photometer described in the section of this paper under Methods and Equipment was put into operation in September, 1938, at which time it was calibrated. After it had been in use for several months it was again calibrated and was found to be defective. Just when it became defective is not known; consequently, all data collected up to mid-April must be treated only qualitatively. After repair the instrument was recalibrated and put into immediate use obtaining quantitative data. Thus, in this paper, instead of expressing data in terms of total illumination at various depths as a percentage of surface light, it has become necessary to state only the greatest depth at which a perceptible light reading could be made with the photometer. The instrument is not sensitive to quantities of light smaller than 1.5 foot candles; therefore, it is assumed that quantities no greater than this existed at depths where no reading could be obtained.

TABLE IV. Maximum Depth of Water, in Meters, At Which the Photometer Recorded Illumination

Date	Depth of Light Penetration in Meters	Date	Depth of Light Penetration in Meters	Date	Depth of Light Penetration in Meters
Sept. 2, 1938	5.0	Nov. 17, 1938	4.0	June 29, 1939	6.0
" 7	4.0	" 22	3.0	July 28	9.0
" 16	4.0	Dec. 5	3.0	Aug. 26	9.0
" 23	5.0	" 15	3.0	" 31	9.0
" 28	5.0	" 19	2.5	Sept. 12	3.0
Oct. 5	4.0	Jan. 10, 1939	3.0	" 19	6.0
" 12	6.5	" 23	4.5	" 25	7.0
" 17	6.5	Feb. 11	7.0	Oct. 3	4.0
" 28	4.0	" 17	5.0	" 9	4.5
Nov. 1	4.5	Mar. 4	8.0	" 21	3.0
" 5	4.5	Apr. 5	0.4	" 26	2.5
" 10	4.0	" 11	0.3		

Table IV contains data obtained by the photometer from September, 1938, to November, 1939, expressing in meters the greatest depths at which light was registered by the instrument. According to these data visible light penetrated to a maximum depth of 9.0 meters, a minimum depth of 0.3 meter, and an average depth of 4.7 meters. Average depth of light penetration for the same periods as discussed for the Secchi disc readings are as follows: September through December, 1938, 4.2 meters; January through March, 1939, 5.5 meters; April, 0.35 meter; June to September, 1939, 8.2 meters; and September to November, 1939, 4.3 meters. In most respects these data correspond closely with those from the Secchi disc readings. Light penetrated to the greatest depths during the time of ice-cover and during the summer months, the least during April, and to intermediate depths from September to November. The effect of an ice-cover on the penetration of daylight into lake water is being investigated, but it will suffice to state here that on several occasions it was found that the ice-cover reflected or absorbed 30 to 50 per cent of the light which fell upon its surface. Until more is known about the influence of an ice-cover on the penetration of daylight into lake water, direct comparisons can not be made between light data obtained through an ice-cover and that obtained in open water.

CHEMICAL DATA

Routine analyses were made at the following depths: surface, 5 meters and 9 meters; however, when marked differences were encountered between these depths additional analyses were made. In general it might be stated that chemical conditions exhibited considerable uniformity from surface to bottom on a given date, but seasonal variations were pronounced. Since vertical distribution of chemical factors is rather uniform it is possible to determine the general chemical conditions by referring to Figure 6, which shows the surface values of each chemical factor investigated.

Dissolved oxygen varied from 5.0 p.p.m. in August and September to 12.9 p.p.m. in March, under the ice-cover (Table V). Variation from surface to bottom did not exceed 2.0 p.p.m. and often it was nearly uniform. Oxygen content of the water was consistently greater during the autumn of 1939, than during the autumn of 1938, which fact can not be explained on the basis of temperature differences (Table I). On several occasions dissolved oxygen showed sudden increases and decreases in content within a period of one week which seems to be related to abundance of organic material in the water, either in the form of plankton or detritus.

Hydrogen-ion concentration (Table VI) varied from 7.5 to 8.4 with the maximum occurring from July to October and the minimum from November to April. From June 14 to 29, the pH was lower than the week preceding or following this period. Irregularities in respect to Ph-th alkalinity, carbon dioxide, and transparency were observed on these same dates. Apparently stormy conditions had stirred up bottom materials, releasing carbon dioxide which brought about the transformation of carbonates into bicarbonates, a lowering of pH, and an increase in turbidity. This one example illustrates how chemical conditions in this region may be altered for short periods by strong winds. No marked variation in vertical distribution of pH was detected despite temporary thermoclines.

TABLE V. Dissolved Oxygen in p. p. m.

Depth in Meters	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Nov. 29	Dec. 5	Dec. 15	Dec. 19
0	5.50	5.12	7.10	6.74	7.60	7.20	7.40	8.46	9.08	6.00	8.60	8.20	8.80	9.71	9.94	12.10	10.60	9.00
5	5.10	5.24	7.22	7.10	8.00	7.46	8.00	7.60	8.68	6.20	8.30	8.06	9.34	9.50	10.56	10.70	10.60	9.76
9	5.00	4.94	7.08	7.66	8.90	7.24	7.20	7.84	8.80	6.00	8.30	7.94	9.36	9.22		10.20	10.50	9.98

Depth in Meters	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	10.70	11.46	10.20	10.80	12.00	10.80	11.20	10.90	12.94	12.00	11.20	11.80	10.70	10.00	9.94	8.81	9.10	8.70
5		11.56	11.30	11.04	11.24	10.50	11.66	10.72	12.06	12.50	11.94	11.20	10.70	10.40	9.66	8.44	10.60	7.90
9		11.36	11.10	11.36	11.70	12.74	10.06	10.82	12.20	12.54	11.56	11.80	9.80	10.60	9.60	8.96	9.20	7.96

Depth in Meters	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
0	8.80	7.70	8.45	7.40	7.50	7.80	7.80	7.60	6.70	5.40	5.60	5.40	8.46	9.00	9.20	10.00	9.80	11.00
5	7.70	9.00	7.45	7.06	7.70	7.60	8.60	6.90	5.80	5.20	5.60	5.40	8.20	8.50	8.40	8.20	9.60	8.10
9	8.14	7.00	7.15	6.34	7.80	6.40	6.86	6.90	6.00	5.34	5.70	7.90	8.14	8.50	8.50	8.20	8.60	8.00

TABLE VI. Hydrogen-ion Concentration

Depth in Meters	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Nov. 29	Dec. 5	Dec. 15	Dec. 19
0	7.9	8.0	8.1	8.1	8.0	8.0	8.0	7.8	7.7	7.7	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6
5	8.0	8.1	8.1	8.1	8.0	8.0	8.0	7.8	7.7	7.7	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6
9	7.9	8.1	8.1	8.1	8.0	8.0	8.0	7.8	7.7	7.7	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6

Depth in Meters	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.6	7.8	7.8	8.2	8.2
5		7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.6	7.8	7.8	8.2	8.2
9		7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.6	7.8	7.8	8.0	8.2

Depth in Meters	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
0	8.2	7.8	7.9	8.3	8.4	8.2	8.4	8.2	8.4	8.4	8.4	8.2	8.4	8.4	8.2	8.2	8.2	8.2
5	8.2	7.7	7.8	8.3	8.4	8.2	8.4	8.2	8.4	8.4	8.4	8.2	8.4	8.3	8.2	8.2	8.2	8.2
9	8.2	7.6	7.7	8.2	8.4	8.2	8.2	8.2	8.4	8.4	8.4	8.2	8.2	8.2	8.2	8.2	8.2	8.2

Table VII. Free Carbon Dioxide in p. p. m.

Depth in Meters	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Nov. 29	Dec. 5	Dec. 15	Dec. 19
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.11	0.45
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.45
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.90	0.45

Depth in Meters	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	0.40	0.60	0.60	0.60	0.60	0.70	0.60	0.60	0.60	2.90	2.10	0.70	0.90	0.60	0.50	0.0	0.0	0.0
5		0.60	0.60	0.60	0.60	0.70	0.60	0.60	0.60	2.90	2.10	0.70	0.90	0.60	0.50	0.0	0.0	0.0
9		0.60	0.60	0.60	0.60	0.70	0.60	0.60	0.60	2.90	2.10	0.70	0.90	0.70	1.00	0.0	0.0	0.0

Depth in Meters	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
0	0.0	0.20	0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.90	0.90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.90	0.90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE VIII. Ph-th Alkalinity in p. p. m.

Depth in Meters	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Nov. 29	Dec. 5	Dec. 15	Dec. 19
0	1.10	1.70	3.40	2.50	2.50	3.90	3.00	3.20	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.90	1.30	2.70	2.20	2.50	3.70	3.20	3.30	0.70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	1.40	1.10	3.20	1.70	2.70	3.80	3.70	3.90	0.80	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0

Depth in Meters	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.00	0.50
5		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.30	0.50
9		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.50

Depth in Meters	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
0	1.00	0.0	0.0	2.00	3.00	1.00	3.00	2.30	2.40	2.50	2.50	4.00	4.40	1.30	0.0	1.00	0.0	0.0
5	1.00	0.0	0.0	1.90	3.00	1.00	3.00	2.30	2.40	2.50	2.00	4.00	4.40	1.30	0.0	1.00	0.0	0.0
9	1.00	0.0	0.0	1.80	3.00	1.00	3.00	2.30	2.50	2.50	2.00	4.00	4.40	1.30	0.0	1.00	0.0	0.0

TABLE IX. Methyl Orange Alkalinity in p. p. m.

Depth in Meters	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Nov. 29	Dec. 5	Dec. 15	Dec. 19
0	95.00	96.90	92.30	92.30	92.40	93.80	94.20	92.70	96.00	93.00	94.50	90.80	92.20	91.70	92.50	90.20	93.40	92.80
5	95.50	96.10	92.00	91.70	92.10	93.40	94.10	92.60	95.50	93.00	93.00	89.80	92.30	92.10	92.50	89.80	93.80	92.40
9	96.00	95.50	91.50	91.30	92.40	92.30	92.70	93.30	93.80	92.50	93.10	90.00	92.40	91.60		90.00	93.90	93.30

Depth in Meters	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	86.30	85.00	84.60	86.00	84.00	83.20	82.00	82.60	86.00	85.50	84.20	83.30	84.80	83.30	89.80	89.10	93.20	88.20
5		85.00	84.50	84.30	82.00	82.10	83.00	83.40	86.00	85.50	84.20	83.30	85.20	85.70	88.70	87.40	91.80	89.30
9		85.00	84.50	84.20	84.00	83.40	82.00	82.00	86.00	85.50	84.20	87.00	84.80	86.50	87.00	88.80	88.50	91.50

Depth in Meters	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
0	92.40	88.30	90.70	89.00	89.20	89.00	92.30	92.20	92.50	92.00	91.50	92.50	91.00	91.00	88.00	88.10	91.30	92.00
5	92.20	91.00	89.20	91.00	90.00	88.00	92.30	92.20	93.00	92.00	92.00	92.50	91.00	91.00	88.00	88.10	91.30	92.00
9	92.00	93.70	91.00	89.00	91.00	88.00	92.30	92.20	93.00	92.00	92.00	92.50	91.00	91.00	88.00	88.10	91.30	92.00

Free carbon dioxide varied from 0.0 to 2.9 p.p.m. from September, 1938, to November, 1939 (Table VII). In general it might be stated that free carbon dioxide was present from December to May and was nearly absent the rest of the year. The maximum carbon dioxide value occurred in April, 1939, during the stormy period which followed the disappearance of the ice-cover. Vertical distribution was almost uniform from surface to bottom for a given date irrespective of season.

Alkalinity of water in the Bass Islands Region (Tables VIII and IX) is due almost entirely to bicarbonates which varied from 96.9 p.p.m. in September, 1938, to 82.0 p.p.m. in March, 1939. In general bicarbonates were present in smaller quantities from January to May than during the rest of the year. Vertical distribution of bicarbonates varied as much as 4.0 p.p.m. from surface to bottom on a given date; however, for the period of investigation it is not possible to state that bicarbonates at one depth were consistently higher or lower than at other depths. Carbonates were absent from September, 1938, to late May, 1939. When present carbonates varied from a minimum of 0.5 p.p.m. in June to a maximum of 4.4 p.p.m. in September.

PLANKTON DATA

PHYTOPLANKTON

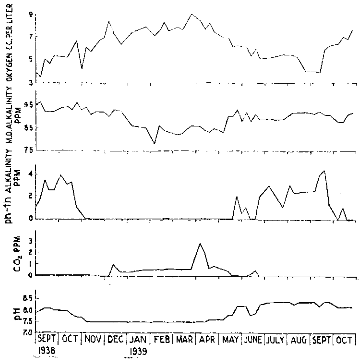
Seasonal Distribution

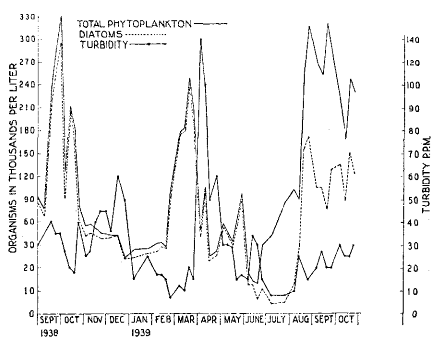
TOTAL PHYTOPLANKTON

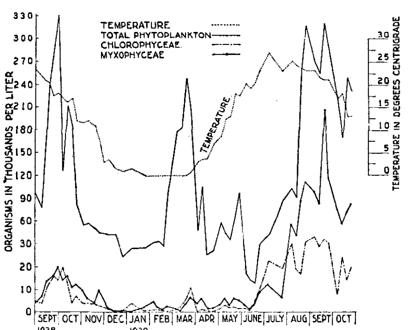
All data pertaining to seasonal distribution and relative abundance of phytoplankton have been derived from an average of collections made from surface, 5 meters, and 9 meters, on a given date. A collection consisted of samples taken from the above depths at one place within the area studied; however, not all collections were made at the same location but were distributed throughout the area from time to time. Nevertheless, all data herein treated have been considered as having come from one station.

General features of seasonal distribution and relative abundance of total phytoplankton are shown in Figure 7 and Table X. It will be noted that definite pulses occurred during the autumn of 1938, and spring of 1939, and again in the autumn of 1939. Pulses of these three periods were approximately of the same size as indicated by the following maxima: autumn of 1938, 330,000 units per liter; spring 1939, 247,000 units per liter; and autumn of 1939, 320,000 units per liter. Duration of the three pulses were as follows: autumn of 1938, 6 weeks; spring of 1939, 8 weeks; and the autumn of 1939, 11 weeks. It should be noted that the entire spring pulse of 1939 occurred under an ice-cover. Fluctuations in quantity of phytoplankton occurred within individual pulses, concerning which no positive explanation can be offered. Data on turbidity (Fig. 7) strongly suggest that many of the fluctuations in quantity of phytoplankters are related to fluctuations in turbidity. However, it is possible that uneven horizontal distribution of phytoplankton within the area may account for these irregularities.

The following list of phytoplankters represents those encountered during quantitative studies, from September 2, 1938, to November 1, 1939. Tiffany (1934) published a qualitative list of plankton algae of this region; thus, the present paper includes only those forms which occurred in sufficient numbers to be considered significant quantitatively. Since identification to species was not practicable in many instances,







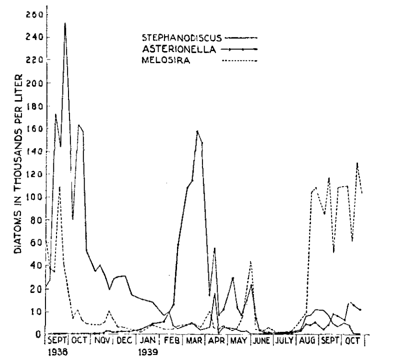


Fig. 6 (upper left). Graphs showing chemical values at the surface for dissolved oxygen, methyl orange alkalinity, Ph-th alkalinity, free carbon dioxide, and pH.

Fig. 7 (upper right). Graphs showing the standing crop of total phytoplankton and total diatoms, in thousands of units per liter, and turbidity in p.p.m.

Fig. 8 (lower left). Graphs showing the standing crop of total phytoplankton, total Chlorophyceae, and total Myxophyceae, in thousands of units per liter, and surface temperature in degrees centigrade.

Fig. 9 (lower right). Graphs showing the standing crop of *Stephanodiscus*, *Asterionella*, and *Melosira*, in thousands of units per liter.

only genus is given. This list consists of 86 algal forms, distributed among the classes as follows: Myxophyceae 17, Chrysophyceae 4, Heterophyceae 2, Bacillariales 23, and Chlorophyceae 40. These forms constituted at least 95 per cent of the total quantity of phytoplankton over the period of investigation. In the following discussion information is given concerning seasonal distribution and relative abundance of the major groups and the more important phytoplankters.

TABLE X. Abundance of Centrifuged Phytoplankton in Thousand, of Units per Liter

Depth in Meters	Group	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Dec. 5	Dec. 15	Dec. 19	Jan. 10 1939
	Myxophyceae..	4.2	7.0	10.4	17.5	20.3	19.6	16.1	10.6	14.7	12.8	5.0	4.3	9.3	6.8	1.8	0.0	1.2	0.0
	Bacillariales...	87.5	60.4	174.3	266.7	257.6	89.7	185.4	101.6	67.2	31.2	43.4	44.4	30.0	38.9	32.2	31.2	19.3	23.7
0	Chlorophyceae	7.0	3.5	9.8	13.3	13.3	19.6	14.0	4.3	4.5	3.2	5.6	4.3	1.2	5.6	3.7	0.0	0.0	4.3
	Miscellaneous.	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total.......	98.7	72.3	194.5	297.5	291.2	128.9	215.5	116.5	86.4	47.2	54.0	53.0	40.5	51.3	37.7	31.2	20.5	28.0
	Myxophyceae..	2.8	9.1	17.5	12.6	20.3	14.7	12.6	15.0	8.7	6.8	5.0	4.3	9.3	3.7	2.1	0.0	0.0	
	Bacillariales...	82.2	68.2	212.1	255.9	309.4	99.9	180.6	214.6	63.2	46.5	40.6	41.2	34.3	39.0	37.8	53.7	26.2	
5	Chlorophyceae	2.8	4.2	7.7	16.1	20.3	25.2	16.1	2.5	7.7	8.1	2.5	3.1	1.2	7.5	0.6	0.0	0.0	
	Miscellaneous.	1.4	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Total.......	89.2	81.5	238.7	284.6	350.0	139.8	209.3	232.1	79.6	61.4	48.1	48.6	44.8	50.2	40.5	53.7	26.2	
	Myxophyceae..	4.2	4.2	12.6	17.5	18.9	8.4	19.7	7.5	12.6	9.3	8.7	4.3	10.0	6.2	1.5	0.0	0.0	
	Bacillariales...	90.2	72.8	239.4	247.8	320.6	86.2	181.1	186.5	56.1	43.1	53.0	40.3	34.2	31.9	47.2	45.9	25.6	
9	Chlorophyceae	3.5	3.5	16.1	18.2	9.8	14.7	10.5	5.6	8.4	1.8	4.3	5.6	7.4	1.8	1.8	0.0	0.0	
	Miscellaneous.	0.0	1.4	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Total.......	97.9	81.9	276.5	283.5	349.3	109.3	211.3	199.6	77.1	54.2	66.0	50.2	51.6	39.9	50.5	45.9	25.6	

TABLE X—(*Continued*)

Depth in Meters	Group	Jan. 23 1939	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 20	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16	May 23	May 30
0	Myxophyceae..	2.5	0.6	2.7	0.6	1.8	1.2	0.6	4.3	7.5	2.4	4.1	1.8	1.4	3.1	5.4	5.8	8.9	7.5
	Bacillariales...	27.1	25.1	29.8	29.0	103.3	158.4	176.8	237.7	188.1	39.3	91.6	23.6	27.7	49.4	31.8	33.1	59.1	94.9
	Chlorophyceae	1.2	0.6	0.6	0.0	0.6	1.2	2.5	6.8	15.0	0.0	5.0	0.0	0.0	1.6	4.3	2.6	2.5	1.2
	Miscellaneous.	0.6	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total.......	31.4	26.3	33.7	29.6	105.7	160.8	179.9	248.8	210.6	41.7	100.7	25.4	29.1	54.1	41.5	41.5	70.5	103.6
5	Myxophyceae..	2.5	10.0	2.5	1.8	4.3	2.0	0.6	2.0	4.3	2.4	5.3	1.9	1.8	1.8	8.1	3.0	5.6	2.0
	Bacillariales...	25.6	26.2	30.9	23.4	111.3	195.2	173.1	242.4	190.9	51.2	95.9	24.3	22.5	60.0	26.8	27.4	56.8	85.2
	Chlorophyceae	0.0	1.2	1.8	0.6	0.0	1.8	3.1	5.0	10.0	0.0	0.0	0.0	0.0	1.2	2.5	1.4	2.7	0.6
	Miscellaneous.	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total.......	28.1	38.0	35.2	25.8	115.6	199.0	176.8	249.4	205.2	53.6	101.2	26.2	24.3	63.0	37.4	31.8	65.1	87.8
9	Myxophyceae..	1.2	2.5	1.2	1.2	1.2	1.2	0.0	4.3	7.5	3.7	7.8	1.2	2.0	4.4	3.7	0.8	3.7	6.2
	Bacillariales...	24.7	29.4	28.5	29.0	99.2	173.7	187.9	234.2	185.0	40.3	107.2	22.5	26.2	51.8	41.3	26.8	46.7	86.5
	Chlorophyceae	0.6	1.2	0.6	0.6	0.0	0.0	2.5	5.6	8.7	0.0	0.0	0.6	0.0	1.8	2.5	1.4	0.6	2.6
	Miscellaneous.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total.......	26.5	33.1	30.3	30.8	100.4	174.9	190.4	244.1	201.2	44.0	115.0	24.3	28.2	58.0	47.5	29.0	51.0	95.3

TABLE X—(*Continued*)

Depth in Meters	Group	June 5 1939	June 14	June 22	June 29	July 8	July 22	Aug. 1	Aug. 11	Aug. 26	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25	Oct. 3	Oct. 9	Oct. 21	Oct. 26
	Myxophyceae..	3.1	1.2	2.2	9.0	12.5	65.7	85.3	40.7	179.3	124.6	125.2	102.0	202.3	113.2	106.6	79.6	78.4	97.2
	Bacillariales...	14.1	18.3	5.5	11.5	4.3	9.5	13.6	14.6	57.0	126.5	103.0	132.6	66.6	79.6	120.9	75.5	143.5	108.5
0	Chlorophyceae	1.2	1.2	5.6	9.3	21.2	15.9	43.6	18.1	17.7	32.4	65.4	36.5	35.9	31.8	11.8	24.6	35.4	23.5
	Miscellaneous.	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total.......	18.4	20.7	13.3	30.4	38.0	91.1	142.5	73.4	255.1	283.5	293.6	271.1	304.8	224.6	239.3	179.7	257.3	229.2
	Myxophyceae..	3.7	0.6	3.3	10.6	21.6	42.5	58.4	42.9	56.0	141.9	96.5	67.4	235.7	120.9	67.2	46.2	63.7	84.3
	Bacillariales...	11.3	10.2	4.7	9.5	3.7	2.4	12.3	23.2	180.5	168.9	104.3	145.7	87.2	134.4	142.7	88.8	141.4	111.5
5	Chlorophyceae	1.2	0.6	3.7	10.1	19.3	25.2	38.9	19.4	20.0	28.2	20.6	26.5	39.3	33.0	15.3	24.7	16.5	23.0
	Miscellaneous.	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.5	1.8	0.0	0.0	0.0	0.0
	Total.......	16.2	11.4	11.7	30.8	44.6	70.1	109.6	85.5	258.2	339.0	221.4	239.6	362.7	290.1	225.2	159.7	221.6	218.8
	Myxophyceae..	1.4	1.2	2.5	6.8	13.3	76.9	25.3	38.2	26.5	69.7	74.3	84.9	182.4	114.5	53.1	46.6	83.3	71.3
	Bacillariales...	12.2	9.3	8.7	11.3	5.0	2.6	11.9	44.1	224.0	223.0	112.0	138.0	76.1	175.2	141.3	102.1	160.0	153.3
9	Chlorophyceae	2.5	0.6	4.3	10.6	27.5	17.7	12.9	20.2	14.1	37.7	32.2	23.6	34.1	30.0	17.6	23.6	23.6	15.3
	Miscellaneous.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0
	Total.......	16.1	11.1	15.5	28.7	45.8	97.2	50.1	102.5	264.6	330.4	218.5	246.5	294.4	319.7	212.0	172.3	266.9	239.9

MYXOPHYCEAE

This group was relatively unimportant qualitatively and quantitatively during the first 10 months of investigation, but it became very important quantitatively during the summer and autumn of 1939 (Fig. 8). The average number of units in thousands per liter of this group from September 2 to December 5, 1938, was 10.5; from December 5, 1938, to July 22, 1939, 3.0; and from July 22, to November 1, 1939, 87.3. At no time from September, 1938, to late June, 1939, did the members of this group exceed 20,000 units per liter, and only during September and October of this period was there any indication of a pulse. Late summer and early autumn of 1939 were characterized by large numbers of this group, a maximum of 210,000 units per liter occurring in late September. The contrast in quantity of this group during the two autumns again suggests the influence of turbidity on plankton production.

Anabaena sp. Occurred during summer and autumn, in quantities not exceeding 2,000 units per liter.

Aphanizomenon flos-aquae (L.) Ralfs, and *Oscillatoria* sp., have been grouped in this study, due to the difficulty of distinguishing one from the other while making the quantitative counts. They were present in most collections and were more numerous than any other members of Myxophyceae. These two forms appeared in quantities varying from 1,000 to 8,000 units per liter from September to December, 1938, with the maximum occurring in September. From January to July, 1939, these forms did not exceed 1,000 units per liter, but a definite pulse began in August and reached a maximum of 104,000 units per liter in late September, 1939.

Aphanocapsa sp. Found in a few collections during August and September, 1939, but never exceeded 2,000 units per liter.

Aphanothece sp. Occurred in the collections of August, 1939, but did not exceed 3,000 units per liter.

Chroococcus limneticus Lemmermann.

Chroococcus turgidus (Kütz.) Näg. No attempt was made to separate *Chroococcus* species in counting. Two peaks of production appeared, October and November, 1938, and July through August, 1939, but they did not exceed 5,000 units per liter.

Coelosphaerium dubium Grunow.

Coelosphaerium naegelianum Unger. No attempt was made to separate these two species in counting. Found during September, 1938, and in July, August, and September, 1939, but in quantities less than 4,000 units per liter.

Gloeotrichia sp. Present in two collections of July, 1939, not exceeding 1,000 units per liter.

Gomphosphaeria lacustris Chodat. Occurred during August and September, 1939, in quantities less than 1,000 units per liter.

Lyngbya sp. Rare.

Merismopedia elegans A. Braun.

Merismopedia glauca (Ehr.) Näg.

Merismopedia tenuissima Lemmermann. Species of *Merismopedia* were not separated in counting. This genus occurred only from September to November, 1938, and from August to late October, 1939. A maximum of 15,000 units per liter occurred in September, 1939.

Microcystis aeruginosa Kütz.

Microcystis flos-aquae (Wittr.) Kirchner. In counting, no attempt was made to separate the different species of *Microcystis*. This genus showed two peaks of production: the first in September, 1938, with a maximum of 7,700 units per liter; the second in August, 1939, with a maximum of 46,000 units per liter. The occurrence of irregular numbers of this genus from week to week explains to a large degree the irregularities of the graph for total Myxophyceae (Fig. 8).

Oscillatoria sp. This form is discussed with *Aphanizomenon*.

CHRYSOPHYCEAE

Dinobryon divergens Imhof.

Dinobryon sertularia Ehr. No attempt was made to separate the species of *Dinobryon*. This genus occurred during spring and summer of 1939, in quantities not exceeding 2,000 units per liter.

Mallomonas alpina Pascher and Ruttner.

Mallomonas caudata Iwanoff. This genus was found only in June, 1939, and did not exceed 1,000 units per liter.

HETEROPHYCEAE

Botryococcus sp. Found in quantities not exceeding 1,000 units per liter from May to October, 1939.

Tribonema sp. Occurred from July to October, 1939, but did not exceed 800 units per liter.

BACILLARIALES

The following statements summarize the general features of this group (Fig. 7): (1) Diatoms were always present and usually constituted the major portion of each collection. (2) Total diatoms exhibited definite pulses during the autumn of 1938, spring 1939, and autumn of 1939. (3) In general diatoms belonging to the order Centrales (*Melosira*, *Cyclotella*, and *Stephanodiscus*) were most numerous in autumn, and those belonging to the order Pennales (*Tabellaria*, *Diatoma*, *Fragilaria*, *Synedra*, and *Asterionella*) were most abundant in spring (Fig. 9). (4) Size and duration of the three diatom pulses were as follows: autumn pulse of 1938, 6 weeks with a maximum of 295,000 units per liter; spring pulse of 1939, 8 weeks with a maximum of 238,000 units per liter; and the autumn of 1939, 11 weeks with a maximum of 175,000 units per liter. A comparison of size and duration of diatom pulses with that of total phytoplankton reveals many similarities (Fig. 7). (5) A winter minimum of 20,000 units per liter occurred in December, 1938, and a summer minimum of 4,000 units per liter occurred in July, 1939. (6) Within each pulse appeared fluctuations in number which apparently are related to fluctuations in turbidity. (7) The spring pulse of 1939 appeared while the ice-cover was present. (8) The maximum of the autumn pulse of 1939 was only 60 per cent of the autumn maximum of 1938. Higher turbidity during the former autumn may be partly responsible for this difference. (9) Average number of diatoms in thousands of units per liter during pulses and between pulses was as follows: September to November, 1938, 157.7; November, 1938, to March, 1939, 33.5; March to April 18, 1939, 146.8; April 18 to August 25, 1939, 29.0; August 25 to November, 1939, 120.0.

Amphiprora sp. Occurred during spring in quantities less than 1,000 units per liter.

Asterionella sp. During the 14 months of investigation this form showed only one pulse which occurred during February, March, and April, 1939, with a maximum of 158,000 units per liter in March (Fig. 9). During the autumn of 1938, it was nearly absent and in the autumn of 1939 it did not exceed 16,000 units per liter.

Cocconeis placentula Ehr. Occurred in spring and autumn collections but did not exceed 1,200 units per liter.

Cyclotella sp. Found in quantities less than 1,000 units per liter during the autumn of 1938, but it appeared during the autumn of 1939, with a maximum of 8,000 units per liter.

Cymatopleura elliptica (Bréb.) W. Smith. Rare.

Cymbella sp. Found only during spring of 1939, in quantities less than 1,000 units per liter.

Diatoma sp. Present in quantities not exceeding 1,000 units per liter during the autumn of 1938, and spring of 1939.

Encyonema sp. Found occasionally in spring collections. Rare.

Fragilaria crotonensis Kitton.

Fragilaria sp. In counting, no attempt was made to separate the different species of *Fragilaria*. This genus was present in most collections and appeared in two pulses, one in March, 1939, with a maximum of 12,000 units per liter, and a second in October, 1939, with a maximum of 8,000 units per liter. Nothing comparable to a pulse occurred in the autumn of 1938.

Gomphonema acuminatum Ehr. Found occasionally in autumn collections, but did not exceed 1,000 units per liter.

Gyrosigma sp. Found throughout the year but did not exceed 1,200 units per liter.

Melosira distans (Ehr.) Kütz.

Melosira granulata (Ehr.) Ralfs.

Melosira varians Ag. In counting, no attempt was made to separate the different species of *Melosira*. This genus reached a maximum of 112,000 units per liter during a pulse in September, 1938, and in June, 1939, another pulse appeared with a maximum of 45,000 units per liter, and finally a pulse extending from August to November, 1939, reached a maximum of 132,000 units per liter. During intervals between pulses this genus was nearly absent (Fig. 9).

Navicula sp. Present in most collections but did not exceed 3,000 units per liter.

Nitzschia sp. Rare.

Rhizosolenia eriensis H. L. Smith. Due to its transparent nature accurate counts of this form could not be made. Apparently it was most abundant from February to June, 1939.

Stephanodiscus spp. This genus showed a pulse in the autumn of 1938, with a maximum of 251,000 units per liter (Fig. 9) and was characterized by abrupt increases and decreases throughout its duration. This form constituted approximately 95 per cent of the total phytoplankton during this period. A small pulse appeared in April, 1939, and again in the autumn of 1939; however, neither of these last two pulses exceeded 18,000 units per liter.

Surirella spp. Found during autumn and spring in quantities not exceeding 1,800 units per liter.

Synedra spp. Two peaks of production appeared, one in March, 1939, with maximum of 48,000 units per liter, and a second in August, 1939, with a maximum of 20,000 units per liter. A secondary pulse with a maximum of 12,000 units per liter appeared in late May, 1939, but it existed for only two weeks.

Tabellaria fenestrata (Lyngbya) Kütz.

Tabellaria flocculosa (Roth) Kütz. This genus was apparently absent from the plankton except from January to June, 1939. It showed only one pulse which occurred in early March, 1939, with a maximum of 11,000 units per liter.

CHLOROPHYCEAE

This group was relatively unimportant quantitatively throughout the period of investigation except during the summer and autumn of 1939. Qualitatively it was one of the most important groups exceeding all others by at least 16 forms. Data on seasonal distribution of total Chlorophyceae (Fig. 8) show that this group produced a small pulse from September to November, 1938, with a maximum of 20,000 units per liter, and another from June to October, 1939, with a maximum of 39,000 units per liter in September. The average number of units in thousands per liter during pulses and periods between pulses was as follows: September to December, 1938, 11.8; December, 1938, to July, 1939, 2.6; and from July to November, 1939, 24.0. Like Myxophyceae this group was more abundant during the autumn of 1939, than in the autumn of 1938.

Actinastrum gracillimum G. M. Smith.

Actinastrum hantzchii Lagerheim. Species of the genus *Actinastrum* were not separated in counting. These forms occurred only in the autumn collections and never exceeded 6,000 units per liter.

Ankistrodesmus convolutus Corda.

Ankistrodesmus falcatus (Corda) Ralfs.

Ankistrodesmus falcatus var. *spirilliformis* G. S. West. In counting, no attempt was made to separate the different species of *Ankistrodesmus*. This genus occurred in quantities not exceeding 1,600 units per liter in the autumn of 1938, but during February and March, 1939, when the ice-cover was present, it reached a maximum of 10,000 units per liter.

Closteriopsis longissima Lemmermann. Found in quantities less than 1,000 units per liter in summer and autumn.

Closterium spp. Occurred in numbers less than 700 units per liter during spring and summer.

Coelastrum microporum Näg.

Coelastrum sp. This genus appeared in about 50 per cent of the collections and was most abundant during the autumn of 1938, with a maximum of 1,400 units per liter, and again during the summer and autumn of 1939, with a maximum of 1,000 units per liter.

Cosmarium spp. Occurred irregularly during spring and summer but never exceeded 600 units per liter.

Crucigenia irregularis Wille.

Crucigenia rectangularis (Näg.) Gay. The genus *Crucigenia* occurred only during September and October, 1938, in quantities not exceeding 1,200 units per liter.

Dictyosphaerium spp. Occurred in two pulses, the first from September to November, 1938, with a maximum of 7,000 units per liter, and a second from late June to mid-November, 1939, with a maximum of 32,000 units per liter. It was apparently absent except for these two periods.

Gloeocystis sp. Rare.

Kirchneriella obesa (W. West) Schmidle. Found during spring, summer, and autumn but never in quantities exceeding 2,000 units per liter.

Lagerheimia citiriformis (Snow) G. M. Smith. Occurred during summer and autumn, 1939, in quantities not excceding 600 units per liter.

Oöcystis borgei Snow.

Oöcystis elliptica W. West.

Oöcystis lacustris Chodat.

Oöcystis submarina Lagerheim. In counting, no attempt was made to separate the different species of *Oöcystis*. This genus appeared during summer and autumn, being most abundant in the autumn, but never exceeding 20,000 units per liter.

Pediastrum boryanum (Turpin) Meneghini.

Pediastrum duplex Meyen.

Pediastrum simplex var. *duodenarium* (Bailey) Rabenhorst.

Pediastrum tetras (Ehr.) Ralfs. In counting, no attempt was made to keep the different species of *Pediastrum* separate. This genus appeared in about 50 per cent of the collections but it did not exceed 5,000 units per liter at anytime. Small pulses occurred during the autumns of 1938 and 1939.

Quadrigula closterioides (Bohlin) Printz.

Quadrigula sp. This genus occurred during the autumns of 1938 and 1939, in quantities not exceeding 700 units per liter.

Scenedesmus acuminatus (Lagerheim) Chodat.

Scenedesmus arcuatus Lemmermann.

Scenedesmus bijuga (Turpin) Lagerheim.

Scenedesmus bijuga var. *flexuosus* (Lemmermann) Collins.

Scenedesmus dimorphus (Turpin) Kütz.

Scenedesmus quadricauda (Turpin) Bréb. In counting, the various species of *Scenedesmus* were not kept separate. This genus occurred in most collections but it never exceeded 3,000 units per liter. It was most abundant during late summer and early autumn.

Schroederia setigera (Schroeder) Lemmermann. Appeared irregularly throughout the year with a pulse occurring from July to September, 1939, with a maximum of 13,000 units per liter.

Selenastrum bibraianum Reinsch. Found only in autumn collections, but did not exceed 1000 units per liter.

Sorastrum spinulosum Näg. Occurred in summer and autumn, with a maximum of 1,600 units per liter.

Sphaerocystis schroeteri Chodat. Rare.

Staurastrum paradoxum Meyen. Rare.

Tetraedron sp. Found during summer months in quantities not exceeding 1,000 units per liter.

Westella botryoides (W. West) de Wildemann.

Westella linearis G. M. Smith. The genus *Westella* appeared in the summer plankton but never exceeded 3,000 units per liter.

Per Cent Composition

Composition and relative abundance of phytoplankton for individual collections, from September, 1938, to October, 1939, are shown in Figure 10. The following is a brief analysis of the seasonal variation in

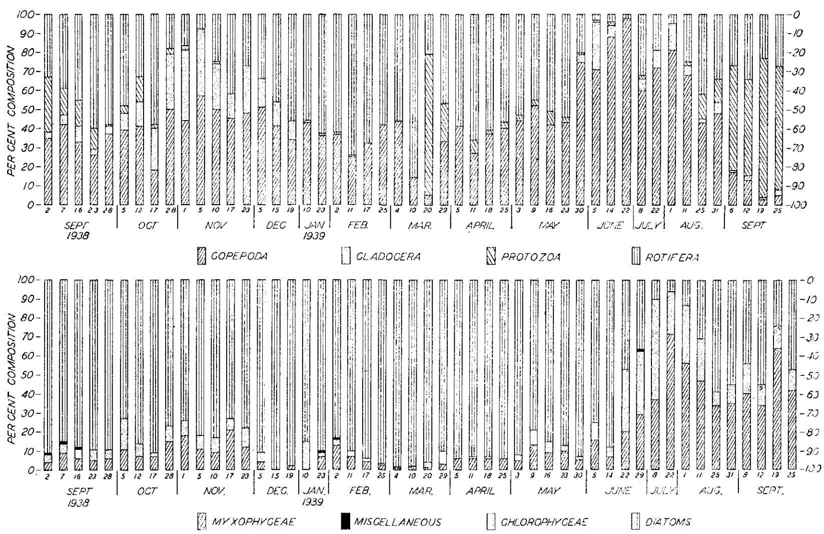


Fig. 10. Graphs showing per cent composition of phytoplankton and zooplankton for individual collections.

composition of this plankton: (1) Diatoms constituted from 5 to 100 per cent of individual collections and were the predominant forms throughout the period of investigation. (2) Diatoms composed at least 70 per cent of the total phytoplankton from September, 1938, to June 22, 1939, and in many instances during this period they constituted 85 to 100 per cent. (3) From June 22, to August 25, 1939, diatoms composed 5 to 48 per cent of the total phytoplankton. (4) From August 25, to September 25, 1939, diatoms made up 25 to 58 per cent of individual collections. (5) Diatoms were not nearly as important a constituent of the plankton during the autumn of 1939, as during the autumn of 1938. (6) Chlorophyceae made up less than 20 per cent, often less than 10 per cent, of individual collections except during the summer months when it averaged 40 per cent of each collection. (7) Myxophyceae composed less than 20 per cent of each collection from September, 1938, to June 29, 1939, but from July to October, 1939, it composed from 30 to 70 per cent of each collection. (8) Myxophyceae and Chlorophyceae in contrast to Bacillariales were more important constituents of the plankton during the autumn of 1939, than during the autumn of 1938. (9) The miscellaneous group, all phytoplankters not belonging to Bacillariales, Chlorophyceae, and Myxophyceae, did not constitute more than 2 per cent of any collection.

Horizontal and Vertical Distribution

No attempt has been made to determine the nature of horizontal distribution of the phytoplankton within the area studied. As previously stated all plankton data in this paper have been derived from weekly collections made at various locations within a limited area. The fact that these data show consistent trends in respect to seasonal variation of plankton groups as well as individuals, indicates that within the area studied horizontal distribution is quite uniform. It is realized that until a systematic study of this subject is made it will not be advisable to apply the present data to areas not covered in this study.

Differences in abundance of phytoplankton at different depths, in the area studied, were found; however, these differences were not great and not consistently of the same nature (Table X). Data in Table X show that at times the greatest quantity of phytoplankton occurs at the surface, while at other times it is most abundant at 5 meters, and still at other times it is greatest at 9 meters. Even Myxophyceae which normally appears in greatest abundance at or near the surface of most lakes, was the most abundant in many instances at the 9-meter depth. This irregular vertical distribution seems to prevail during spring and autumn when complete circulation is continuous, but under the ice-cover and during mid-summer when circulation is not so evident there are indications that phytoplankters are more consistent in their vertical distribution (Table X). Since vertical distribution of phytoplankton in the Bass Islands Region is irregular it is believed that an average of collections from the three chosen depths gives adequate data to determine the standing crop for a given date.

Zooplankton

Seasonal Distribution

Total Zooplankton

Most data pertaining to zooplankton have been derived from an average of the collections made at the surface, 5 meters, and 9 meters on a given date. Previous work in this region has shown that this method furnishes reliable data in respect to the standing crop. However, studies based on collections at intervals of 1 meter from surface to bottom are in progress and will furnish information on vertical distribution which is lacking in this paper.

Seasonal trends of the standing crop of total zooplankton is shown in Figure 11. This graph reveals that a pulse occurred during the autumn of 1938, and extended to mid-December; the spring pulse of 1939 occurred from mid-April to late June; the autumn pulse of 1939 appeared from August to October. The maximum of the autumn pulse of 1938 apparently occurred before this investigation began, but there are reasons for believing that this pulse was similar to that of the autumn of 1939, except that it appeared a few weeks earlier. The spring

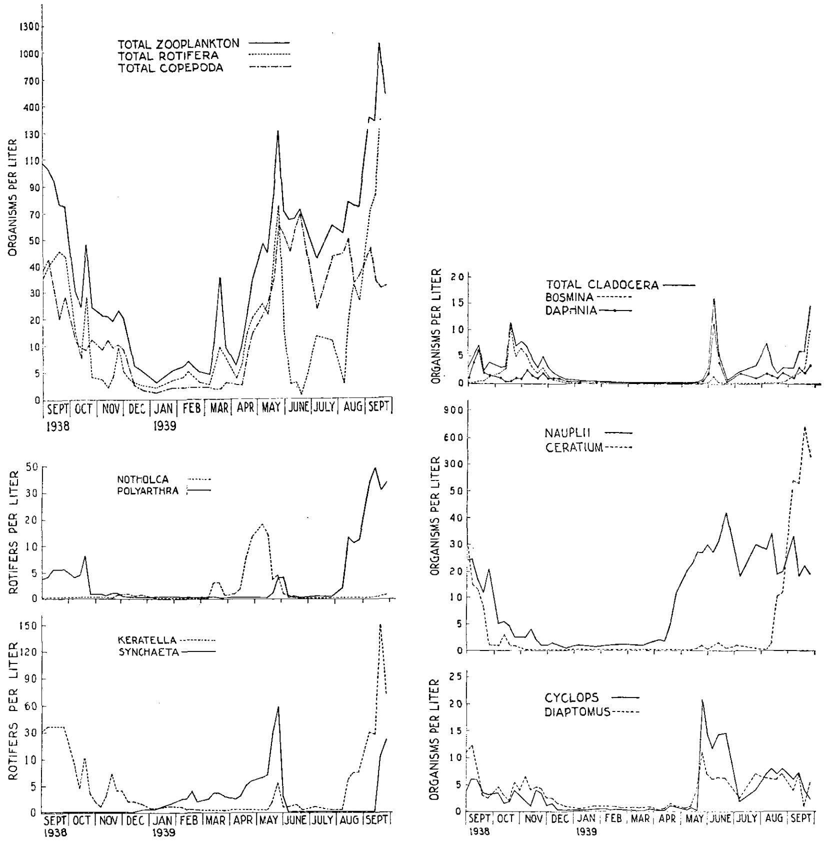


Fig. 11 (upper left). Graphs showing the standing crop of total zooplankton, total Rotifera, and total Copepoda per liter.

Fig. 12 (lower right). Graphs showing the standing crop of *Notholca*, *Polyarthra*, *Keratella*, and *Synchaeta* per liter.

Fig. 13 (right). Graphs showing the standing crop of *Bosmina*, *Daphnia*, Nauplii, *Ceratium*, *Cyclops*, *Diaptomus*, and total Cladocera per liter.

zooplankton pulse of 1939 began at the termination of the spring phytoplankton pulse and reached its peak in late May. Due to the fact that copepods and rotifers did not attain their maxima at the same time, this spring pulse is irregular in appearance and extends over most of three months. Beginning in August the quantity of zooplankton increased gradually until it reached a peak in September. It will be noted that a marked difference exists between the winter minimum of 3 per liter and the summer minimum of 23 per liter. A large portion of this summer zooplankton was composed of immature stages of copepods (Fig. 13). Many of the abrupt but temporary fluctuations appearing in the graph representing total zooplankton (Fig. 11) are due to sudden increases in quantity of a single genus or even species. Difference in size of spring and autumn pulses of 1939, is due primarily to greater abundance of protozoa during the latter period.

A complete understanding of the nature of seasonal variation of total zooplankton can be obtained only through knowledge of seasonal variation of the constituent plankters. The following section gives the salient features of predominant zooplankters and major zooplankton groups in respect to seasonal abundance. In some instances identification to species was not feasible; thus only genus is given. The list of zooplankters discussed consists of 52 forms, distributed among the major zooplankton groups as follows: Protozoa, 10; Rotifera, 21; Cladocera, 8; and Copepoda, 13.

Protozoa

Members of this group were relatively unimportant qualitatively and only during late summer and early autumn were they important quantitatively. Average number of Protozoa per liter for different times of the year was as follows: September to November, 1938, 8; November, 1938, to March, 1939, 0.0; March to August 25, 1939, 3; August 25, to September 25, 1939, 250. Average for the year was only 33 per liter.

Ceratium hirundinella (O. F. Müller) Schrank. Occurred only in autumn collections (Fig. 13).

Codonella cratera (Leidy). Occurred from June to September, 1939, with a maximum of 66 per liter.

Diffulgia lobostoma Leidy.

Diffulgia sp. This genus appeared irregularly throughout spring, summer, and autumn, especially during periods of violent water agitation. Following a stormy period it appeared in numbers of 400 per liter.

Epistylis sp. Occurred irregularly throughout summer months but did not exceed 10 per liter.

Holosticha sp. Appeared in collections of March, 1939, in numbers of 25 per liter.

Peridinium spp. Found during autumn of 1938, but did not exceed 3 per liter.

Trichophyra epistylidis Claparède and Lachmann. Occurred in the summer of 1939, in numbers not exceeding 8 per liter.

Vorticella sp. Present in most collections, usually attached to diatoms, but did not exceed 15 per liter.

Zoothamnium arbuscula Ehr. Found throughout summer months in quantities not exceeding 12 per liter.

Rotifera

Rotifers were present in all collections and ranked with copepods in abundance. Data on seasonal distribution of total Rotifera (Fig. 11) show definite pulses during the autumn of 1938, and the spring and autumn of 1939. The autumn pulse of 1938 was irregular in nature and did not exceed a quantity of 45 per liter; the spring pulse reached a maximum of 75 per liter in May, 1939; and the autumn pulse of 1939, reached a peak of 250 per liter in late September. Average number of rotifers per liter during pulses and periods between pulses was as follows: September to November, 1938, 32; November, 1938, to April 18, 1939, 5; April 18, to June 5, 1939, 30; June 5, to August 11, 1939, 5; August 11, to September 25, 1939, 91.

Asplanchna herrickii de Guerne.

Asplanchna priodonta Gosse. This genus occurred in quantities not exceeding 4 per liter during spring and autumn.

Brachionus angularis Gosse. Appeared sporadically throughout the year but most abundant from July to September. Maximum number encountered was 17 per liter.

Chromogaster ovalis (Bergendal). Rare.

Collotheca mutabilis (Hudson). Occurred from July to October with a maximum of 18 per liter in August, 1939.

Colurella sp. Rare.

Conochilus unicornis Rousselet. Found in July and August collections with a maximum of 32 per liter.

Euchlanis sp. Found during spring, summer and autumn, in numbers not exceeding 3 per liter.

Filinia longiseta (Ehr.). Present from April to August but did not exceed 10 per liter.

Gastropus stylifer Imhof. Rare.

Keratella cochlearis (Gosse). Occurred in all collections but appeared in pulses only during the autumns of 1938 and 1939 (Fig. 12). It is one of the most abundant rotifers in this region, exhibiting a maximum of 150 per liter.

Keratella quadrata (Müller). Occurred in winter and spring collections but did not exceed 6 per liter.

Monostyla sp. Found in spring and summer, not exceeding 4 per liter.

Notholca longispina (Kellicott). Found in most collections and produced a pulse during April and May, 1939 (Fig. 12).

Notholca striata (Müller). Found only during March, 1939, in numbers not exceeding 6 per liter.

Ploesoma truncatum (Levander). Occurred in spring and summer collections, but did not exceed 4 per liter.

Polyarthra euryptera Wierzejski.

Polyarthra trigla Ehr. In counting no attempt was made to separate the species of *Polyarthra*. This genus showed a pulse each autumn during September and October and a small pulse during May and June, 1939 (Fig. 12).

Synchaeta sp.

Synchaeta stylata Wierzejski. In counting, no attempt was made to separate the two species of *Synchaeta*. This genus appeared in two pulses, one during April and May, 1939, with a maximum of 70 per liter, and a second during September, 1939, with a maximum of 40 per liter (Fig. 12).

Trichocera longiseta (Schrank). Found in spring collections but did not exceed 5 per liter.

Trichocera sp. (Diurella group). Rare.

CLADOCERA

Cladocerans were never abundant constituents of the plankton but they did show seasonal variation (Fig. 13). A pulse of cladocerans occurred from September to mid-December, 1938, with a maximum of 12 per liter, but from this time until May, 1939, they were apparently absent from the plankton. A spring pulse, with a maximum of 17 per liter, appeared in June, 1939; a summer pulse with a peak of 8 per liter occurred in August; and the autumn pulse with a maximum of 16 per liter appeared in September, 1939. Irregularity of the graph showing total Cladocera is due to the fact that the 8 species involved had their maxima occurring at different times. The average number of cladocerans per liter during the two pulses was as follows: September to mid-December, 1938, 4.4; May 23, to September 25, 1939, 5.0.

Bosmina longirostris (O. F. Müller). Occurred in the plankton from September through December, 1938, with a maximum of 10 per liter. It appeared in quantities of 2 per liter in June, 1939, and again in August and September, 1939, with a maximum of 10 per liter (Fig. 13). The average number of this species during each autumn pulse was 3 per liter.

Ceriodaphnia reticulata (Jurine). Occurred during July and August, 1939, in numbers not exceeding 3 per liter.

Daphnia longispina (O. F. Müller). Occurred from September to December, 1938, with a maximum of 6 per liter and an average of 2 per liter. A pulse with a maximum of 9 per liter appeared in May and June, 1939, and from July to October, 1939, it was present in numbers not exceeding 3 per liter. The average number per liter from May to October was 3. This species was more abundant than any other cladoceran and had a seasonal distribution similar to that shown for total Cladocera (Fig. 13).

Daphnia pulex (de Geer). Found in quantities not exceeding 3 per liter during spring and summer.

Daphnia retrocurva Forbes. Occurred at about the same time as *D. longispina* but always in numbers less than 4 per liter.

Diaphanosoma leuchtenbergianum Fischer. Occurred from May through September, 1939, with a maximum of 3 per liter.

Leptodora kindtii (Focke). Found from May to September, never exceeding 1 per liter.

Sida crystallina (O. F. Müller). Rare.

COPEPODA

General characteristics of seasonal distribution of total copepods are shown in Figure 11. This group was most abundant during autumn and spring at which times pulses appeared. The pulse during the autumn of 1938 probably reached its peak in August before this investigation was begun, although there were 40 per liter present in early September. A spring pulse occurred from early April to mid-July, 1939, with a maximum of 70 per liter in late June. In July the summer minimum of 20 per liter occurred but by August the number had increased to 40 per liter and this level was maintained to mid-September, 1939. It may be noted that the autumn pulse of 1938, and the spring pulse of 1939, were separated by a winter minimum of 2 per liter which existed from mid-December, 1938, to mid-April, 1939. This winter minimum is a sharp contrast, both in size and duration to the summer minimum which separated the spring and autumn pulses of 1939. Immature and adult stages of *Cyclops* and *Diaptomus* made up the bulk of copepod plankton and the following data on average number of these forms during pulses and between pulses will aid in visualizing the relative importance of these forms. Average number of adult *Cyclops* per liter from September through December, 1939, was 3; from January to May 23, 1939, 0.4; from May 23 to October, 1939, 11.0. Average number of *Diaptomus* per liter from September through December, 1938, was 5; from January to May 16, 1939, 0.7; from May 16 to September 25, 1939, 6.0. Average number of nauplii per liter from September to November 17, 1939, was 9; from November 17, 1938, to April 18, 1939, 1; from April 18 to September 25, 1939, 24. It will be seen from these data that nauplii were predominant at all times but especially so from May to October, 1939. Figure 13 shows the general features of seasonal variation of nauplii.

In the following discussion quantitative data are given for all species of copepods except *Diaptomus*. In many instances identification of female *Diaptomus* to species was not attempted; therefore, only general statements are made concerning the members of this genus.

Canthocamptus staphylinoides Pearse. Found in April and May in quantities of 1 per liter.

Cyclops americanus Marsh. Occurred from May to November but did not exceed 3 per liter.

Cyclops bicuspidatus Claus. Found throughout the year but most abundant in May and June, with a maximum of 7 per liter.

Cyclops brevispinosus Herrick. Occurred in most collections but was most abundant from April to September, with a maximum of 6 per liter.

Cyclops leucharti Claus. Occurred in most collections but most numerous from June to September, with a maximum of 6 per liter.

Cyclops prasinus Fischer. Found in collections from April to October, with a maximum of 4 per liter in August.

Diaptomus ashlandi Marsh. Occurred in most collections but was most abundant from May to September.

Diaptomus minutus Lilljeborg. Found from June to September.

Diaptomus oregonensis Lilljeborg. Occurred in most collections, but most numerous from April to September.

Diaptomus sicilis Forbes. Found in most collections but was most abundant in June.

Diapomus siciloides Lilljeborg. Present in collections from September to November, 1938, and during March and August, 1939.

Epischura lacustris Forbes. Occurred from April to October with a maximum of 8 per liter in August.

Limnocalanus macrurus Sars. Found in collections during the months of February and May, in quantities less than 1 per liter.

Per Cent Composition

Composition of individual plankton collections, made from September, 1938, to October, 1939, is shown graphically in Figure 10. In most instances Rotifera and Copepoda composed the greatest percentage of each collection and of these two, Copepoda was the most important component. Protozoa and Cladocera were of secondary importance and ranked about equal in respect to per cent composition. The following is a brief analysis of data pertaining to per cent composition of this plankton. (1) Protozoa in most cases did not constitute more than 20 per cent, usually less than 10 per cent, of total zooplankton from September, 1938, to September, 1939. However, during the month of September, 1939, this group composed from 50 to 70 per cent of the total zooplankton, due to a large pulse of *Ceratium*. (2) Cladocera composed from 10 to 38 per cent of the total zooplankton from early October to mid-December, 1938, but was relatively unimportant the rest of the year except for a few collections during June, July, and August, 1939. (3) Rotifers composed 30 to 85 per cent of the total zooplankton of all collections except those from late October to mid-December, 1938, and from late May to early August, 1939. This group was most important from late December, 1938, to May, 1939. (4) Copepods composed 40 to 60 per cent of the total zooplankton from late October through December, 1938, and 60 to 96 per cent of the zooplankton from late May to mid-August, 1939. Other times of the year this group composed less than 30 per cent of the total zooplankton. (5) Periods during which copepods composed significant percentages of the total zooplankton coincided with similar periods for Cladocera. Rotifers were most abundant in the plankton when Cladocera and Copepoda were least abundant.

Horizontal and Vertical Distribution

During this study little attention was given to the subject of horizontal distribution of zooplankton. The fact that the present data, based on weekly collections, yield rather consistent results in respect to seasonal trends of the zooplankton population indicates that horizontal distribution must be fairly uniform within the area studied. Wright and Tidd (1933) found that plankton Crustacea were not uniformly distributed in the "Island Section," but there was no evidence that they were consistently abundant at certain stations and consistently rare at others.

A limited amount of information pertaining to vertical distribution of zooplankton in the area studied is shown in Table XI. It may be noted that surface collections contained fewer zooplankters than collections from the other depths and the 5 meter-depth contained the largest number of plankters. Rotifera and Protozoa show a very irregular distribution, sometimes appearing in greater numbers at the surface, other times greater at one of the other depths. The Crustacea, however, show the normal distribution in that greater numbers occur at deeper levels during the day. Studies based on diurnal collections made at various times of the year are in progress and will furnish additional data on vertical distribution.

TABLE XI. Abundance of Zooplankton in Numbers per Liter

Depth in Meters	Group	Sept. 2 1938	Sept. 7	Sept. 16	Sept. 23	Sept. 28	Oct. 5	Oct. 12	Oct. 17	Oct. 28	Nov. 1	Nov. 5	Nov. 10	Nov. 17	Nov. 23	Dec. 5	Dec. 15	Dec. 19
0	Protozoa...	29.2	10.0	12.0	22.0	0.5	0.7	4.9	0.3	1.0	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0
	Rotifera...	29.3	35.0	45.0	44.0	26.5	8.9	7.8	46.9	4.7	2.9	0.6	5.2	8.9	4.0	2.2	1.9	1.1
	Cladocera..	0.5	2.0	8.0	1.0	1.3	1.0	0.7	1.1	6.3	3.0	7.9	0.9	2.1	1.6	0.2	0.5	0.0
	Copepoda..	31.6	37.0	26.0	19.0	26.0	6.5	7.4	1.8	7.2	5.4	9.8	6.1	7.8	5.8	4.5	1.8	0.9
	Total....	90.6	84.0	91.0	86.0	54.3	17.1	20.8	50.1	19.2	11.7	18.3	12.3	18.8	11.4	6.9	4.2	2.0
5	Protozoa...	40.0	20.0	15.0	2.0	0.6	1.1	2.0	1.2	0.5	0.8	0.0	0.0	0.1	0.1	0.0	0.0	0.0
	Rotifera...	46.0	36.0	39.0	53.0	63.8	15.7	6.9	27.7	4.2	3.8	1.4	4.8	12.1	5.5	4.1	4.8	3.2
	Cladocera..	3.8	5.0	8.0	3.0	4.9	4.1	5.3	21.5	6.5	16.3	6.4	8.2	4.8	3.0	1.0	0.5	0.9
	Copepoda..	46.0	38.0	29.0	21.0	36.6	13.7	10.8	16.4	10.2	12.2	9.4	11.5	12.3	9.8	5.7	2.0	1.6
	Total....	135.8	99.0	91.0	79.0	105.9	34.6	25.0	66.8	21.4	33.1	17.2	24.5	29.3	18.4	10.8	7.3	5.7
9	Protozoa...	25.0	16.0	12.0	2.0	1.5	1.9	2.0	0.8	1.0	0.1	0.0	0.3	0.0	0.0	0.0	0.1	0.0
	Rotifera...	30.0	50.0	45.0	40.0	38.2	19.2	8.1	10.3	3.5	4.1	3.3	3.9	7.7	5.6	5.3	2.0	3.5
	Cladocera..	2.6	7.0	5.0	3.0	2.5	3.5	2.7	9.9	7.5	3.8	7.7	4.5	2.1	10.1	3.9	1.3	0.6
	Copepoda..	37.0	56.0	39.0	18.0	19.6	15.7	10.6	8.4	18.6	9.6	16.9	10.7	10.9	11.7	7.4	4.0	2.0
	Total....	94.6	129.0	101.0	63.0	61.8	40.3	23.4	29.4	30.6	17.6	27.9	19.4	20.7	27.4	16.6	7.4	6.1

TABLE XI. (*Continued*)

Depth in Meters	Group	Jan. 10 1939	Jan. 23	Feb. 2	Feb. 11	Feb. 17	Feb. 25	Mar. 4	Mar. 10	Mar. 20	Mar. 29	Apr. 5	Apr. 11	Apr. 18	Apr. 25	May 3	May 9	May 16
0	Protozoa...	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	25.0	0.3	0.0	0.3	0.5	0.5	1.5	0.4	5.9
	Rotifera...	1.5	2.1	5.0	4.3	2.5	2.1	3.2	8.1	9.8	2.8	2.8	4.6	10.7	16.0	16.7	13.0	41.2
	Cladocera..	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.3	0.0	0.0	0.2
	Copepoda..	1.6	0.3	1.7	0.5	0.6	2.0	0.2	1.6	1.4	2.0	2.0	3.2	6.0	8.3	13.5	19.0	19.5
	Total....	3.1	2.4	6.8	4.9	3.1	4.2	3.4	9.7	36.2	5.1	4.8	8.3	17.2	25.1	31.7	32.4	66.8
5	Protozoa...	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	27.1	1.8	0.0	1.0	0.5	1.0	1.7	1.6	6.7
	Rotifera...	1.8	4.4	3.2	6.1	5.1	3.2	3.7	10.7	5.7	5.3	4.8	6.5	13.3	16.9	33.0	20.8	51.9
	Cladocera..	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.5
	Copepoda..	1.0	2.8	2.2	3.2	2.3	1.9	2.3	1.3	1.1	3.2	3.1	1.3	8.0	14.2	29.1	40.0	41.9
	Total....	2.9	7.3	5.4	9.4	7.4	5.2	6.0	12.0	33.9	10.3	8.0	8.8	21.8	32.1	63.9	62.4	101.0
9	Protozoa...		0.0	0.0		0.0	0.0	0.0	0.0	25.0	3.0	0.0	0.8	0.3	1.6	1.5	1.6	4.0
	Rotifera...		3.4	3.6		4.9	2.6	1.1	9.5	6.9	4.0	3.2	7.6	14.8	26.5	26.2	30.5	34.2
	Cladocera..		0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.1
	Copepoda..		2.5	3.1		2.7	2.5	3.4	1.7	2.7	3.2	2.3	3.0	9.9	19.7	21.3	16.2	43.5
	Total....		5.9	6.7		7.6	5.1	4.5	11.2	34.6	10.2	5.6	11.4	25.0	47.9	49.1	48.3	81.8

TABLE XI. (*Continued*)

Depth in Meters	Group	May 23 1939	May 30	June 5	June 14	June 22	July 8	July 22	Aug. 1	Aug. 11	Aug. 25	Aug. 31	Sept. 6	Sept. 12	Sept. 19	Sept. 25
	Protozoa	5.9	0.3	0.5	3.0	0.3	1.2	0.0	0.0	1.7	17.6	1.2	203.6	148.0	807.2	190.8
	Rotifera	52.9	15.8	3.5	3.8	0.9	4.9	0.4	0.3	18.6	22.6	29.2	114.2	87.4	244.0	205.2
0	Cladocera	0.6	1.0	1.6	1.4	0.1	0.3	2.5	0.1	0.7	0.2	0.2	1.8	3.6	3.9	16.2
	Copepoda	25.4	46.8	42.0	45.8	15.9	10.3	47.6	0.7	43.7	19.0	31.0	67.8	24.0	30.4	22.8
	Total	84.8	63.9	47.6	54.0	17.2	16.7	50.5	1.1	64.7	59.4	61.6	387.4	263.0	1085.5	435.0
	Protoxoa	2.8	0.2	1.0	1.1	0.1	0.8	0.2	0.0	1.4	7.6	15.6	172.0	130.0	690.0	495.0
	Rotifera	125.9	13.2	2.4	1.1	0.5	27.8	32.0	4.9	25.3	39.8	30.8	54.2	89.2	237.6	135.2
5	Cladocera	0.9	0.9	37.7	5.9	0.8	2.3	9.0	14.7	5.6	2.8	8.4	2.4	7.6	6.6	13.8
	Copepoda	104.2	52.1	56.0	36.7	39.3	32.9	52.4	92.7	69.9	40.6	42.2	29.8	44.4	33.0	39.6
	Total	233.8	66.4	97.1	44.8	40.7	63.8	93.6	112.3	102.2	90.8	97.0	258.4	271.2	967.2	683.6
	Protozoa	2.0	0.4	1.0	0.4	0.0	0.3	0.0	0.0	1.3	6.0	9.2	67.6	96.0	980.0	453.0
	Rotifera	45.8	13.4	1.1	3.7	0.8	3.8	1.7	2.6	13.7	34.6	18.4	42.6	71.6	268.8	129.4
9	Cladocera	0.4	5.6	8.2	4.6	0.0	4.4	5.3	7.8	6.1	2.0	4.0	4.8	6.4	6.6	15.0
	Copepoda	47.6	59.5	39.2	89.0	155.4	26.8	30.4	39.5	44.7	39.8	34.8	40.8	31.4	29.4	34.8
	Total	95.8	78.9	49.5	97.7	156.2	35.3	37.4	49.9	65.8	82.4	66.4	155.8	205.4	1284.8	632.2

DISCUSSION

Data presented in this paper, derived from a 14 months study of water in the Bass Islands Region of Lake Erie (Fig. 2) resemble in certain respects the data obtained from a general limnological survey of a much larger area, the "Island Section," conducted by the U. S. Bureau of Fisheries and the Ohio Department of Conservation during the spring, summer, and autumn of 1928, 1929, and 1930 (Wright and Tidd, 1933). This similarity suggests that weekly collections made in the Bass Islands Region may give information that is representative of a large portion of the western end of Lake Erie. The following discussion deals with the major features of the Bass Islands Region in respect to plankton and the environmental factors which influence it.

The shallow water of the Bass Islands Region, not exceeding 12 meters in depth, is kept in complete circulation throughout the year except during brief calm periods in spring and summer when conditions are favorable for thermal stratification. Only three times during the investigation was thermal stratification encountered and then it was only temporary in nature, producing little or no effect on the vertical distribution of chemical factors. It might be concluded that this part of Lake Erie resembles a sublittoral zone in respect to thermal and chemical conditions. The primary effect of the ice-cover which existed from January to April, 1939, was that of preventing violent churning of the water by wind. This resulted in lower turbidity even though the water was kept in complete circulation by currents. It is possible that during severe winters an extensive ice-cover may produce conditions different from those observed during the winter of 1938–39, but it appears that under most winter conditions water is kept in complete circulation. The fact that a phytoplankton pulse occurred under the ice-cover indicates that water conditions under the ice were not greatly different from those of the open lake.

Turbidity is believed to be one of the most important physical factors operating in the shallow waters of this area; however, present data do not justify conclusive statements. Examination of Figure 7 gives the impression that phytoplankton pulses occur at times of relatively low turbidity and small phytoplankton populations exist at times of high turbidity. Each phytoplankton pulse, autumn 1938, spring and autumn 1939, occurred when turbidity was relatively low, and periods between pulses were characterized by higher turbidity. Likewise, abrupt decreases and increases in quantity of this plankton during a pulse is seemingly related to fluctuations in turbidity, but a statistical treatment of these data does not yield a significant coefficient of correlation between turbidity and abundance of plankton. If turbidity does affect phytoplankton production it is likely that it is accomplished by influences antecedent to time of collection rather than on date of collection. Thus, it becomes necessary to make daily observations on turbidity and abundance of plankton during spring and autumn when the greatest fluctuations of both occur. Other investigators have reported data similar to that shown in Figure 7. Harris and Silvey (1940) in their work on Texas reservoir lakes found that maxima plankton productions occurred at times of low turbidity in Lake Worth and Lake Bridgeport but in Lake Dallas and Eagle Mountain Lake maxima plankton productions occurred at times of high turbidity. Daily (1938) studied the phytoplankton of Lake Michigan in the vicinity of Evanston, Illinois, and states, "From weekly studies, it was difficult to ascertain the exact relation between turbidity and plankton pulses; however, the increases in turbidity appear to precede the plankton pulses." The writer believes that a positive correlation does exist between low turbidity and large phytoplankton pulses in this region but this subject awaits further investigation. If turbidity influences abundance of zooplankton it is probably accomplished indirectly through its effect on phytoplankton.

It is conceivable that large quantities of sediment in suspension could injure plankters through mechanical action or by carrying them to the bottom during settling. The writer (Chandler, 1937) observed such effects from studies of lake plankton entering a river. Another evident way by which turbidity can effect phytoplankton production is through reduction of the intensity of illumination at various depths, thus limiting the depth at which photosynthesis can occur. Examination of data on light penetration as determined by the Secchi disc and photometer (Tables III and IV) shows that light was often absent or greatly reduced below depths of 5 meters. Marked variations in depths to which light penetrated occurred daily as well as seasonally, as is indicated by daily turbidity readings (Table II and Fig. 7). The maximum depth to which light penetrated, according to photometer readings, was 9 meters during the summer of 1939, and the minimum was 0.3 meter in April, 1939. An average for the 14 months was 4.7 meters. It appears from these data that light conditions are such that phytoplankters at certain times are able to carry on photosynthesis at all levels from surface to bottom while at other times photosynthetic processes are limited to the upper meter of water. It must be kept in mind that the effect of light on abundance of phytoplankton is due to causes antecedent to time of collection and not at time of collection. High turbidity lasting several days would result in reduced photosynthesis in phytoplankters which would be reflected later in a reduced population. If this application be carried farther it is possible to understand how the degree of turbidity during spring, summer, and autumn might determine the time, duration, and size of phytoplankton pulses.

Unfortunately no information can be offered concerning the qualitative nature of light at various depths in the water of this region. It is known (Birge and Juday 1930, 1931) that turbid waters have a selective effect on transmission of spectral rays. Transmission of shortwave radiations is more affected by suspended materials than transmission of longer wave lengths. It becomes apparent that the effects of turbidity on plankton production can best be approached through a qualitative and quantitative study of light at various depths and the investigation of light requirements of individual plankters for photosynthesis.

Chemical data obtained in this investigation (Tables V–IX) show that chemical conditions vary with the season but differences in vertical distribution from surface to bottom were not significant for a given date.

There are no indications that chemical factors, dealt with in this paper, might have a limiting effect on plankton production. An investigation of dissolved inorganic elements in waters of this area has been carried on simultaneously with this plankton study, and there are indications that some of these elements may be limiting in effect. A discussion of the cycle of dissolved inorganic elements in the waters of this region and their influence on plankton populations will be the subject of another report.

Phytoplankton pulses occurred in the autumn of 1938, and spring and autumn of 1939; however, these three differed from each other in several respects and also from the pulses reported by Wright and Tidd (1933) in the "Island Section." The autumn pulse of 1938 occurred from early September to late October with a maximum of 330,000 units per liter appearing in late September (Fig. 7). This pulse was dominated by diatoms which constituted approximately 80 per cent of the total phytoplankton at this time. *Stephanodiscus* alone composed 75 per cent of the diatoms of this pulse but this form was nearly absent the following autumn. The autumn pulse of 1939 extended from mid-August to mid-October with a maximum of 320,000 units per liter occurring in late September. Diatoms were dominant during this pulse but in contrast to the previous autumn they never composed more than 60 per cent of the total phytoplankton and often less than 50 per cent. Chlorophyceae and especially Myxophyceae contributed much more heavily to this pulse than that of the previous autumn. Turbidity and depth of light penetration (Fig. 7 and Table IV) were very similar during the autumns of 1938 and 1939, especially at the time of phytoplankton pulses, but antecedent to the pulses these factors were different for the two autumns. Average depth to which light penetrated during July and August, 1938, based on four photometer readings, was 3.0 meters while for the same period during 1939 it was 8.0 meters. It would appear that more favorable light conditions of the second year resulted in larger quantities of greens and blue-greens but fewer diatoms. It is quite possible that the different algal forms have different light requirements and that turbidity and depth of light penetration just preceding the pulse influence the abundance of the various groups during the pulse.

The spring pulse of 1939 occurred from late February to early April with a maximum of 247,000 units per liter occurring in late March. Diatoms composed about 90 per cent of this plankton but no one genus was dominant since *Asterionella*, *Fragilaria*, *Synedra*, and *Tabellaria* contributed heavily to this pulse. This entire pulse occurred while an ice-cover was present. Apparently the ice-cover had very little effect on water conditions as reflected by plankton, temperature, and chemical data. Mild winter conditions resulted in a restricted ice-cover limited to the Bass Islands Region, with open water on all sides. This restricted ice field formed a bridge between islands, underneath which the water circulated freely and no doubt mixed with water of the open lake. It might be expected that an ice-cover would reduce turbidity of the water through protection from wind action but during 1939 the water was more turbid during winter than summer. Apparently the turbid water of the open lake mixed to some extent with the ice-covered water. Possibly the conditions of this particular winter are not typical of winters in general but this study does furnish some interesting data that may be of considerable value when compared with data from other winters. Temperature records during this pulse indicate little change from that of the previous two months and suggest that temperature in itself has little influence on the periodicity of diatoms. Wright and Tidd (1933) reported that the maxima of the spring pulses of 1929 and 1930 occurred in late May and early June. If water temperatures of those years were at all similar to those of a corresponding time in 1939, the plankton pulse must have occurred when the water was 17.0° C. which is 16 degrees higher than when the spring pulse of 1939 occurred.

Wright and Tidd (1933) state that the average abundance of phytoplankton groups, in thousands of units per liter, for the period late May to early October of 1929 and 1930 was as follows: diatoms, 90; greens, 38; blue-greens, 58. Similar data obtained in 1939 for the same period are as follows: diatoms, 76; greens, 20; blue-greens, 63. It is evident that diatoms and greens were more abundant in 1929 and 1930 than for the same period in 1939, while the blue-greens were less abundant. Since the spring pulse of 1939 occurred much earlier than it did in 1929 and 1930 the above data probably are not comparable. To make them comparable the spring pulse of 1939 should be included in the averages. When this is done the average for the diatoms becomes 123 instead of 76, but the other groups are affected very little. It appears from these data that the quality and quantity of phytoplankton in 1929, 1930, and 1939 were quite similar for comparable periods, even though the pulses did not occur at corresponding times.

Zooplankton pulses occurred during the following periods: September to November, 1938; April to July, 1939; and August to October, 1939. No one plankton group dominated all three pulses as is indicated by the following: autumn of 1938, Copepoda and Rotifera contributed about equally; spring of 1939, Rotifera and Copepoda were equally important during the first part of the period while Copepoda was predominant in the latter part; autumn of 1939, Protozoa was dominant. It is apparent that composition of this plankton varies from season to season for the same year and likewise it varies from year to year for corresponding seasons. Phytoplankton and zooplankton pulses appeared at approximately the same time in the autumns of 1938 and 1939, but the phytoplankton pulse, during the spring of 1939, preceded the zooplankton pulse by 6 weeks; however, a secondary phytoplankton pulse occurred along with this zooplankton pulse. Dependence of zooplankton pulses upon phytoplankton pulses is problematical but the two usually occur at about the same time rather than being widely separated as reported here. The spring phytoplankton pulse of 1939 appeared several weeks earlier than it did during the springs of 1929 and 1930; however, the zooplankton pulses for the three years occurred at about the same time (May-June).

A comparison of certain zooplankton data based on a survey of the "Island Section" of Lake Erie (Wright and Tidd, 1933) with that of the present investigation reveals some interesting facts. Wright and Tidd state, "Nothing is known definitely regarding abundance in the months of December, January, February and March, but there are reasons for believing that crustacea are rare during that period. During the remaining months, the adult crustacea were rare in spring and autumn and were most abundant in summer. In 1930 copepod larvae were most abundant in late spring and probably the same was true in 1929." Data from the Bass Islands Region show that during December, January, February, and March the average number of adult plankton crustacea was 2.0 per liter, which confirms the above statement. However, in this region adult plankton crustacea were most abundant in May and June, and September, while the summer population, though rather large, was smaller than the above periods (Fig. 13). Nauplii were slightly more abundant in spring than in autumn but an almost uniform number with a mean count of 24.0 per liter existed from late April to October, 1939.

The four most abundant genera of plankton Crustacea in the "Island Section" were *Cyclops*, *Diaptomus*, *Daphnia*, and *Diaphanosoma*, and the mean count per liter for each during the period late May to early October, for the years 1929 and 1930, was as follows: *Cyclops*, 10; *Diaptomus*, 6; *Daphnia*, 4; and *Diaphanosoma*, 1. Mean counts of these same genera based on data from the Bass Islands Region for a corresponding period in 1939 are as follows: *Cyclops*, 11; *Diaptomus*, 6; *Daphnia*, 3; and *Diaphanosoma*, 0.5. There is a marked similarity between these two sets of data which suggests that plankton data derived from the Bass Islands Region are representative of the entire "Island Section."

Practically no data on Protozoa and Rotifera were presented in the summary report of the investigation of the "Island Section" by Wright and Tidd, but these groups were found to be numerically important in the plankton of the Bass Islands Region. Rotifera ranked next to Copepoda in per cent composition of total zooplankton, and during winter months it constituted a greater percentage of total zooplankton than any other group. It is quite possible that Wright and Tidd used a coarser meshed net for zooplankton collections than was used during the present investigation, thus allowing many Protozoa and Rotifera to escape. From the standpoint of fish food, Rotifera and Protozoa are relatively unimportant in comparison with Cladocera and Copepoda, but nevertheless these groups must be considered as important constituents of the plankton.

SUMMARY

1. Year-round limnological data based on weekly collections in the region of the Bass Islands, Lake Erie, are presented. Emphasis is placed on seasonal variation of centrifuged phytoplankton, net zooplankton, and certain physical and chemical conditions characteristic of the region.

2. Water, with a maximum depth of 12 meters in this region, circulates from surface to bottom throughout most of the year, due to currents and wind action. This results in

nearly uniform vertical distribution of chemical factors, temperature, turbidity, and phytoplankton.

3. From late December, 1938, to late March, 1939, an ice-cover existed, through which winter collections were made. The ice-cover being confined to this island region apparently formed a bridge between islands, allowing water beneath it to mix freely with water of the open lake.

4. Turbidity is believed to be one of the most important physical factors influencing the productivity of the water in this region. It varied from 3 to 140 p.p.m. and was greatest at times of low plankton production and lowest at times of high plankton production.

5. Maximum depth to which total light penetrated into water varied from 0.3 meter in April to 9 meters during July and August; average for the year was 4.7 meters.

6. Data in this paper suggest that turbidity influences the quality and quantity of light available at various depths for photosynthesis, which in turn may influence the time, duration, and size of phytoplankton pulses.

7. Definite phytoplankton pulses occurred as follows: early September to late October, 1938, with a maximum of 330,000 units per liter; late February to early April, 1939, with a maximum of 247,000 units per liter; mid-August to mid-October, 1939, with a maximum of 320,000 units per liter.

8. Diatoms constituted from 50 to 100 per cent of total phytoplankton except during summer months.

9. Chlorophyceae and Myxophyceae together composed 50 to 90 per cent of the total phytoplankton during June, July, and early August.

10. Composition of phytoplankton differed considerably in the two autumns. In 1938, diatoms constituted from 70 to 90 per cent of the total, while Myxophyceae and Chlorophyecae together composed only 10 to 30 per cent; in 1939, diatoms composed 25 to 55 per cent while Myxophyceae and Chlorophyceae together constituted from 45 to 75 per cent of the total.

11. A phytoplankton pulse with a maximum of 247,000 units per liter occurred under the ice-cover during March, 1939.

12. Zooplankton pulses occurred as follows: September to November, 1938; April to July, 1939; August to October, 1939.

13. Rotifera and Copepoda, about equal in abundance, together composed 40 to 95 per cent of the total zooplankton from September, 1938, to September, 1939. During September, 1939, Protozoa constituted 48 to 72 per cent of the total.

14. Zooplankton and phytoplankton pulses of the two autumns coincided, but the spring phytoplankton pulse terminated before the zooplankton pulse began; a difference of 10 weeks existed between maxima of the two pulses.

15. Physical, chemical, and plankton data of this study resemble in many respects similar data derived from a study of a large portion of the western end of Lake Erie, by Wright and Tidd in spring, summer, and autumn of 1929 and 1930. This suggests that weekly collections in the region of the Bass Islands may supply data that are representative of a large portion of the western end of Lake Erie.

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